The Biogeography and Host Plant Utilisation of Eucalypt Feeding Coreidae (Hemiptera: Heteroptera)

by

Martin James Steinbauer
B.Agr.Sc.(Hons) (Tas.)

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requirements for the degree of
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Department of Agricultural Science
University of Tasmania
and the
Co-operative Research Centre for Temperate Hardwood Forestry
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Dedication

This thesis is dedicated to the memory of my grandparents, Denis Ronald and Joyce Page, who fostered my interest in biology from an early age. They are greatly missed.

Declaration

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma in any tertiary institution and that, to the best of my knowledge and belief, contains no material previously published or written by another person, except when due reference is made in the text of the thesis.

Martin James Steinbauer

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Martin James Steinbauer

Abstract

In Tasmania, Australia, the family Coreidae (Hemiptera: Heteroptera) is represented by three species; *Amorbus obscuricornis* (Westwood), *Gelonus tasmanicus* (Le Guillou) and *Acantholybas kirkaldyi* Bergroth. Of these, *A. obscuricornis* and *G. tasmanicus* are host specific for plants of the genus *Eucalyptus* (Myrtaceae), with the former feeding almost exclusively upon shoots and the latter feeding at various sites.

Initial uncertainty as to the identity of the coreids within Tasmania lead to the taxonomy of the three genera being reviewed. These studies showed that *Amorbus*, a genus of 20 plus species, is represented in Tasmania only by *A. obscuricornis*; while *Gelonus tasmanicus* was confirmed as being a monospecific genus. Rediscovery of individuals of *A. kirkaldyi*, known previously only from the type description, allowed a formal revision of this genus to be undertaken.

The distributions of *A. obscuricornis* and *G. tasmanicus* were found to include much of Tasmania and south-eastern Australia. In Tasmania, coreids were noticeably absent from the western half of the island where the vegetation is almost devoid of eucalypts. Both species were found to be univoltine in Tasmania. The phenology of *A. obscuricornis* appears to coincide particularly well with seasonal growth phenology of *Eucalyptus*. Aspects of these species' developmental and reproductive biologies are used to support hypotheses concerning their biogeography and host plant utilisation.

No-choice host plant performance studies revealed that *A. obscuricornis* would feed and lay eggs on all *Eucalyptus* species offered. Nymphs of this species were also able to eclose on most eucalypts tested. *G. tasmanicus* was only able to reach adulthood on *E. regnans* and *E. delegatensis*. For *A. obscuricornis*, performance indicators such as adult survival, egg production and weight of offspring were influenced by the quality of the hosts' shoots, in particular the C/N ratio and water content; while the reduced host range of *G. tasmanicus* is suggestive of a more important role of secondary plant substances in the species.

The oligophagous habit of *A. obscuricornis* and *G. tasmanicus* for eucalypts was confirmed by field sampling. General observations suggested that *A. obscuricornis* preferred hosts which were coppicing after being physically damaged and a field based experiment investigated this issue. Epicormic buds were induced by canopy removal,

simulating the effect of fire. Sampling of control and coppicing eucalypts revealed the complete absence of *A. obscuricornis* nymphs from non-coppicing trees. C/N and water content analyses of coppicing and control hosts revealed that coppice shoots were nutritionally superior to normal shoots.

In the discussion I relate the biogeography and host plant utilisation of *A. obscuricornis*, in particular, to the degree of polyphagy exhibited by that species. I argue that the selection pressure imposed on *A. obscuricornis* by an environment where the supply and quality of eucalypt shoots is unpredictable, has favoured the evolution of an oligophagous feeding strategy. That the species is oligophagous for plants belonging to the one genus is possible given the ubiquity of *Eucalyptus* species in the Australian environment.

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List of Publications Arising from this Research

STEINBAUER, M.J. and CLARKE, A.R. (In review). Revision of the genus *Acantholybas* Breddin (Hemiptera: Coreidae). *Ann. Ent. Soc. Am.*

STEINBAUER, M.J. (1995). A note on manna feeding by ants. *J. nat. Hist.* (in press).

STEINBAUER, M.J. and DAVIES, N.W. (1995). Defensive secretions of *Amorbus obscuricornis* (Westwood), *A. rubiginosus* (Guérin-Méneville) and *Gelonus tasmanicus* (Le Guillou) (Hemiptera: Coreidae). *J. Aust. ent. Soc.* **34:** 75-78.

STEINBAUER, M.J. and CLARKE, A.R. (1995). *Xenoencyrtus hemipterus* (Girault) (Hymenoptera: Encyrtidae), an egg parasitoid of Coreidae (Hemiptera) in Tasmania. *J. Aust. ent. Soc.* **34:** 63-64.

(Reprints are provided in the back pocket of this thesis. In all instances, experimental work and preparation of manuscripts was undertaken by myself while coauthor Dr Anthony Clarke is included as a supervisor and for editing draft manuscripts and Dr Noel Davies is included for conducting the gas chromatography-mass spectrometry analyses in collaboration with myself.)

List of Personal Communicators

BARTON-BROWNE, L. C.S.I.R.O. Division of Entomology, P.M.B. 3, Indooroopilly, Qld, 4068.

BASHFORD, R. Forestry Tasmania, G.P.O. Box 207B, Hobart, Tas., 7001.

BERRYMAN, A.A. Department of Entomology, Washington State University Pullman, WA 99164-6432, U.S.A.

COWLEY, D.R. School of Biological Science, The University of Auckland, Private Bag 92019, Auckland, N.Z.

DAVIS, P. Department of Classics, University of Tasmania, Sandy Bay, GPO Box 252C, Hobart, Tas., 7001.

de LITTLE, D.W. North Forest Products, P.O. Box 63, Ridgley, Tas., 7321.

DUNGEY, H. Department of Plant Science, University of Tasmania, Sandy Bay, GPO Box 252C, Hobart, Tas., 7001.

ELLIOTT, H.J. Forestry Tasmania, G.P.O. Box 207B, Hobart, Tas., 7001.

ELLIS, R. C.S.I.R.O. Division of Forestry, Locked Bag 2, P.O. Sandy Bay, Tas. 7005.

GROSS, G. South Australian Museum, North Terrace, Adeliade, S.A., 5000.

LANSBURY, I. Hope Entomological Collections, Oxford University Museum, Parks Road, Oxford, OX1 3PW, U.K.

MADDEN, J.L. Department of Agricultural Science, University of Tasmania, Sandy Bay, GPO Box 252C, Hobart, Tas., 7001.

McCLAY, A. Alberta Environmental Centre, Bag 4000, Vegreville, Alberta T9C 1T4, CAN.

McQUILLAN, P. Department of Geography and Environmental Studies, University of Tasmania, Sandy Bay, GPO Box 252C, Hobart, Tas., 7001.

RATKOWSKY, D. Department of Agricultural Science, University of Tasmania, Sandy Bay, GPO Box 252C, Hobart, Tas., 7001.

SCHEUKER, B. Forestry Tasmania, Geeveston, Tas. 7116.

SHATTUCK, S. Australian National Insect Collection, C.S.I.R.O. Division of Entomology, Box 1700, Canberra, A.C.T., 2601.

TURNBULL, C. C.S.I.R.O. Division of Forestry, Locked Bag 2, P.O. Sandy Bay, Tas. 7005.

Chapter 1

Introduction

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1.1. An Introduction to the Family Coreidae (Hemiptera: Heteroptera).

Members of the superfamily Coreoidea are considered to be primarily endemic to the tropics and subtropics (Schaefer 1965; Dolling 1991; McGavin 1993; Schuh and Slater 1995). Coreoid bugs are distinguished from the closely related lygaeid bugs by means of a series of longitudinal accessory veins in the membrane of the hemelytra and from the largids and pyrrhocorids by having ocelli (Carver *et al.* 1991). Adults of a few species are brightly coloured, however, the majority are dark and drab and all are plant feeders (Schaefer 1965; Cobben 1978; Schuh and Slater 1995). In Australia, this superfamily comprises some 76 species of which 57 belong to the family Coreidae (Carver *et al.* 1991). The Coreidae are generally moderate to large, robust insects which release strong repellent odours when disturbed. The three insect species whose taxonomy, biology and ecology are discussed in this thesis (namely *Amorbus obscuricornis* (Westwood 1842) (Fig. 1.2), *Gelonus tasmanicus* (Le Guillou 1841) (Fig. 1.3) and *Acantholybas kirkaldyi* Bergroth 1909) are all members of this insect family.

The Coreidae are commonly referred to as the squash bug family (Naumann 1993), a common name stemming from the North American species, *Anasa tristis* DeGeer, which is a pest of squash (family Cucurbitaceae). Some authors have also referred to members of this family as leaf-footed bugs, which relates to the ornate nature of the femora and tibiae of many species (Miller 1956; Mitchell 1980a). Goodchild (1977) referred to the shoot feeding bug, *Mygdonia tuberculosa* Sign (Coreidae), as "bow-legged bugs" as a result of their strongly curved hind legs.

Australian coreids, particularly those found on native trees, have not had a notable history as pests and have not been given a widely used common name. Froggatt (1907) and Elliott *et al.* (1990) used the name "gumtree bugs" to refer to these insects, however, Tillyard (1926) rightly considered that this name lacked sufficient distinction. The even more inappropriate name (because of an association with *Mictis profana* (F.) (Coreidae)) "crusader bugs" was used by Evans (1943) when referring to members of the genus *Amorbus* Dallas. Waterhouse *et al.* (1961) referred to *Amorbus rubiginosus* (Guérin-Méneville) as "eucalyptus bug", while Carne *et al.* (1980) used "amorbus bugs" to refer to the members of this genus. Species of coreid bug from South Africa, which have

similar feeding habits to *Amorbus*, are called "twig wilters" (Bevis 1964 in Schaefer and O'Shea 1979) and a similar version of this common name would seem appropriate to *Amorbus*; for example "eucalypt tip wilting bug" or "eucalypt tip wilters".

Naumann (1993) used the common name "gelonus bugs" to refer to species of insect belonging to the genus *Gelonus* Stål. The apparent rarity of *Acantholybas kirkaldyi* has meant that it has never been given a common name. In Tasmania, following their recent recognition as "minor pests" (Elliott and de Little 1985; Bashford 1992), both *A. obscuricornis* and *G. tasmanicus* have become widely referred to as "coreid" bugs after the family to which they belong.

1.2. The Economic and Ecological Importance of the Coreidae.

As with many other insect families, details regarding the biology and ecology of coreid bugs has been gleaned from the study of pest species within the group. Some of these pest species include *Anasa tristis* DeGeer (Beard 1940), *Amblypelta* spp. Stål (Donaldson 1983; Bigger 1985), *Aulacosternum nigrorubrum* Dallas (Carver *et al.* 1991), *Cletus punctiger* Dallas (Ito 1984), *Leptoglossus gonagra* (F.) (Carver *et al.* 1991), *L. phyllopus* (L.) (Mitchell 1980a) and *Mictis profana* (F.) (Carver *et al.* 1991; Flanagan 1994). However, members of the Coreidae have also received attention as a result of the noticeable defensive secretions they produce (Waterhouse *et al.* 1961; Waterhouse and Gilby 1964; McCullough 1970, 1972, 1973, 1974; Baker *et al.* 1972; Aldrich and Yonke 1975), whilst a number of works have been dedicated to the taxonomy of various genera within the group (for example Kumar 1965; Schaefer 1965; Donaldson 1983; Brailovsky 1993).

Members of the genus *Amorbus* have long been noted as being associated with and/or damaging the growing tips of eucalypts (Fig. 1.2) (Froggatt 1907; Tillyard 1926; Evans 1943; McKeown 1945; Kumar 1966; Martyn *et al.* 1970; Carne and Taylor 1978; Hardy *et al.* 1979; Marks 1985; Stone 1991, 1993; Miles and Taylor 1994) and even those of other plants (i.e. *Rosa* sp. shoots, Martyn *et al.* 1973). However, it was not until recently that the potential threat *Amorbus*, in particular, posed to plantation eucalypts (Fig. 1.1) was recognised (Green 1972; Carne and Taylor 1978; Elliott and deLittle 1985; Elliott *et al.* 1990; Ohmart 1990; Stone 1991, 1993; Bashford 1992, 1993). This rise to prominence is a reflection of the increasing importance of eucalypt plantation forestry in Australia, particularly in the island state of Tasmania.

Figs 1.1-1.3. Photographs of: **(1.1)** a one year old plantation of *Eucalyptus delegatensis* in the Florentine Valley, Tasmania; **(1.2)** an adult *Amorbus obscuricornis* ♂ feeding on an *E. obliqua* shoot; **(1.3)** an adult *Gelonus tasmanicus* ♂ feeding on the midrib of a young *E. nitens* leaf.

The three Tasmanian coreid genera include *Gelonus*, *Acantholybas* Breddin and *Amorbus*. Of the three genera, *Amorbus* is best documented, whilst the other two have received almost no study. To-date the only biological/ecological studies that have concentrated on the Tasmanian coreids are those by Green (1972) and Bashford (1992).

1.3. The Reasons for Studying Tasmanian Coreids.

The reasons for studying coreids can be divided into two distinct areas. The first area is of local relevance and is related to the significance of these insects to plantation forestry in Tasmania and Australia. The second area is of broader ecological importance and concerns the insect-plant interactions of large, mobile, sucking insects.

Locally, the desire to better understand the Tasmanian Coreidae arose from the observations of forest managers during the late 1980's and early 1990's of damage to plantation eucalypts in north-west Tasmania caused by coreid feeding (J. Madden, University of Tasmania, pers. comm.). These observations were given additional weight following the publication of the findings of Bashford (1992), who demonstrated that coreid bugs were able to cause damage to plantation eucalypts, but appeared to be spasmodic pests, reaching high population densities in some years but not in others. Indeed, this factor has meant that these insects have never been the target of insecticide control in Tasmania (H. Elliott, Forestry Tasmania and D. de Little, North Forest Products pers. comm.). This spasmodic occurrence posed the question of why coreid populations reach high densities in some years and not in others and what factor/s might be responsible for these fluctuations? Answering this question was initially intended to be the focus of the research effort of this thesis.

Upon addressing this question it became apparent that many aspects of coreid taxonomy and almost everything concerning their biology and ecology were only partly understood, or completely unknown. Thus, the need for basic biological data pertaining to these insects became obvious. Such information would provide a better understanding of these insects and enable foresters to formulate management responses appropriate to the dual needs of economic and environmental sustainability.

Of wider ecological and evolutionary interest is the study of insect-plant interactions of large, mobile, sucking phytophagous insects; a group which has received significantly less attention than other herbivorous groups, the chewing insects in particular. Many insect-plant studies use chewing insects, presumably because such insects: **(a)** readily

accept both excised vegetation and artificial diets, making confinement and rearing of experimental insects comparatively easy; **(b)** can often be found in very large numbers making collection for experimentation relatively simple; and perhaps most importantly **(c)** their damage is highly apparent and easily quantifiable, as opposed to quantifying fluid intake which is considered to be more difficult (Buntin 1985; Gullan and Cranston 1994).

The sessile and semi-mobile sucking insects, such as aphids, psyllids and planthoppers (members of the Sternorrhyncha and Fulgoroidea) have also received some attention. These insects are amenable to the investigation of their host plant relationships because: **(a)** sessile insects remain on plants for chosen investigation periods and thus do not require confinement; **(b)** the generally small size of these insects readily allows them to be confined to chosen substrates upon which they may be reared in large numbers; **(c)** these insects are phloem feeders (Carver *et al.* 1991), hence their dietary requirements have been well documented and are comparatively simple; **(d)** these insects are also often locally very abundant making collection of large numbers easy; and lastly **(e)** in many instances these insects are vectors of plant disease (Miles 1972).

In contrast, insect-plant interactions of the large, highly mobile sucking phytophagous insects have historically received comparatively less investigation. This is because: **(a)** unless these insects feed on excised generative or vegetative plant parts (such as the lygaeid seed feeder *Neacoryphus bicrucis* (Solbreck 1978)) maintaining such large insects on living tissue in confined conditions is difficult; **(b)** these insects are not exclusively phloem feeders (Carver *et al.* 1991), hence their diet maybe complex and in many cases their nutritional requirements are poorly understood or completely unknown; **(c)** these large insects are often widely dispersed spatially and have short temporal durations (Yen 1989) making collection difficult; and lastly **(d)** they do not commonly vector plant diseases (Miles 1972).

Presently, the significance of both host plant secondary compounds (i.e. plant defensive chemistry, as per Fraenkel 1959, 1969 and "digestibility reducing compounds" such as resins, tannins and silica, Feeny 1970, 1975, 1976) and nutritional quality (Kennedy and Booth 1951; Kennedy 1958) are acknowledged as vital factors influencing insect-plant associations (Mitchell 1980a). As hemipterous insects would appear to have the capacity to avoid secondary plant defences and possibly also digestibility reducing compounds, by virtue of the possession of piercing-sucking mouthparts, the significance of Fraenkel's theory of host plant selection to such insects requires investigation (Mitchell 1980a;

Schaefer and Mitchell 1983). It may be that different ecological factors, such as plant phenology, nutrient quality or abundance, influence the host selection mechanisms of piercing-sucking insects (Schaefer and Mitchell 1983; Kidd *et al.* 1990; Leather 1990; Major 1990). Much of this thesis looks at this issue.

1.4. Eucalypt Production in Australia: A Brief Introduction.

Prior to European settlement of Australia, nearly 10% of the continent was covered by native forest (defined as "vegetation of mostly single stemmed trees growing to over 5 metres in height, and with a canopy cover of more than 30%" (Forest Industries 1992a)). Since then, approximately one third of the forests have been cleared for agricultural production and urban development (Forest Industries 1992a). Presently, Australia has approximately 43.2 million hectares of native forest, of which 17 million hectares is protected (Forest Industries 1992c). Approximately 92% of native forests and woodlands in Australia are characterised by the dominance of species of tree belonging to the genus *Eucalyptus* (Morrow 1977a; Carne and Taylor 1978).

The genus *Eucalyptus* (family Myrtaceae) consists of over 500 species, nearly all of which are endemic to Australia (Chippendale 1988). Members of the genus range from trees to shrubs and mallees (defined as a growth form in eucalypts in which several stems arise from a lignotuber). The bark may be either fibrous, stringy, smooth or tessellated and most species are heterophyllous, i.e. having morphologically distinct seedling, juvenile, intermediate and adult leaves. Flowers typically occur in groups of 3 or more per umbel, rarely singularly, with the calyx and/or the corolla forming a small cap (operculum). Eucalypts occur in most regions of Australia but have attained their greatest diversity in the near-coastal areas of New South Wales and in south-west Western Australia (Chippendale 1988).

Whilst some agricultural crops have been subject to domestication for approximately 9,000 years (Harlan 1970), eucalypts have been deliberately cultivated for less than 200 years (Turnbull 1991) following European settlement of Australia in 1788. Some 40,000 years prior to this, however, Aborigines had been using eucalypt leaves to make water-based infusions for the treatment of bronchial ailments and to promote rapid healing of wounds (Boland *et al.* 1991). Of the 8 million hectares of eucalypts now established worldwide, "more than 90% of these forests have been planted since 1955 and about 50% in the past decade" (Turnbull 1991). In Australia the area given to eucalypt plantations by the end of 1993 was 124,880 ha and was expanding at the rate of 14,350

ha per annum (Table 1.1). This represents a major increase in the total area of eucalypt plantations, which was estimated to be 28,000 ha in 1976 (Cromer and Turnbull 1994). These plantations are almost entirely located in temperate Australia; namely Tasmania, Mt. Gambier district South Australia, Australian Capital Territory, New South Wales, eastern Victoria and south-west Western Australia (Whyte 1992). Approximately half of the Australian eucalypt estate is managed for pulpwood production, where the main eucalypt species grown are *Eucalyptus nitens* (Dean & Maid). Maid. (Shining gum) and *E. globulus* Labill. (Tasmanian/Southern blue gum or Blue gum) (Tibbits 1986; Whyte 1992).

Table 1.1. Area (ha) of *Eucalyptus* plantation in Australia and rate of new planting.

State	Total area to end of 1993	Annual rate
New South Wales	26,500	500
Victoria	22,400	2,850
Tasmania	48,080	6,000
Western Australia	26,600	5,000
Queensland	1,300	0
Total area	124,880	14,350

Tasmania has the largest eucalypt estate of any Australian state estimated at 48,080 ha (Table 1.1). Forestry based industry (native forests and plantations) is a major source of revenue for Tasmania. In 1986-87 an estimated A$1 billion was generated from forest products (20% of revenue from primary industry) (Smith 1994), providing employment for 11.9% of Tasmania's work force (C.R.E.A. 1991). For Australia as a whole the forest industry is the country's second largest manufacturing industry with an annual sales turnover of approximately A$10 billion, employing some 85,000 people (Forest Industries 1992b).

In Tasmania (and elsewhere in Australia) sawlog production presently uses existing "native old growth" forests and "old regrowth" forests (Forest Industries 1992c; H. Elliott pers. comm.). Some of the main species logged in Tasmania include *E. regnans* F. Muell. (Stringy/Swamp gum or Mountain ash), *E. obliqua* L'Hérit. (Brown-top/Messmate stringybark), *E. delegatensis* R. Baker (White-top stringybark and Alpine ash) and *E. globulus*. The practice of establishing regrowth forests of *E. regnans* and *E. obliqua* on previously logged sites for sawlog production will continue to be the main method for the production of trees for sawlogs, particularly as the clearing of native old

growth forests is further restricted (H. Elliott pers. comm.). Under the Intensive Forest Management (IFM) Scheme (H. Elliott pers. comm.) the use of plantations to produce sawlog timber is being trialled in Tasmania. Tasmania is the only state presently undertaking such investigations. Through the IFM Scheme some 3,000 ha of *E. nitens* plantation was established by the end of 1993. It is planned that this acreage will be increased to 6,500 ha by the end of 1995 and will have a 30 to 45 year rotation (H. Elliott pers. comm.).

As eucalypt plantations represent such a valuable resource, with a high cost of establishment (upwards of A$2, 000 per ha, Whyte 1992), it is necessary to protect the productivity of the existing resource and ensure that future plantation establishment is a viable proposition in both economic and environmental terms. In part, this can only be assured if the technical and managerial skills are available to make investment in eucalypt plantations attractive to investors (Whyte 1992). However, this type of information can only be gained through the generation of adequate biological knowledge about pests and diseases (Kile 1992). This thesis helps generate some of this knowledge.

1.5. Insect Management in Forestry and the Need for Basic Research.

Criticism of insect pest control, in particular the excessive use of certain types of pesticides, has been mounting since the late 1950's. This criticism has been fuelled by concerns relating to the development of resistance by pest species, hazards to human health and welfare and the resurgence of pest populations (both primary and secondary) due to the elimination of biotic control factors (Geier 1966; Broadley 1982; Sill 1982; Sagar 1991). The root of this criticism is to be found in the historical development of pest control, which Geier (1966) considered as being: "Conceived as a mere exercise in technology, pest control amounts to hardly more than bulldozing nature without thought to consequences, and frequently creates more problems than it solves." In other words, research into the control of an insect pest was driven from the "operations end" of the production process and hence sought only immediate, or short-term, solutions which took little, or no account, of possible medium to long-term outcomes. Research often only sought to answer the question: "How can this pest be controlled?"

The literature stands as testament to the failings of the "bulldozer" approach to pest control. Some of the more notable failures include the control programs for *Aspidiotus perniciosus* (Comstock) (Hemiptera: Diaspididae) (Broadley 1982), *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) (Geier 1981; Thwaite *et al.* 1993), *Heliothis armigera*

(Hübner)/*H. punctigera* Wallengren (Lepidoptera: Noctuidae) (Zalucki *et al.* 1986), *Icerya purchasi* Maskell (Hemiptera: Margarodidae) (Gullan and Cranston 1994), *Musca domestica* L. (Diptera: Muscidae) (Broadley 1982) and *Schistocerca gregaria* Forskål (Orthoptera: Acrididae) (Joern and Gaines 1990; Whitten 1992). When we consider the reasons behind each of these pest control failures, common causes include the reliance upon simplistic insecticide application schedules coupled with insufficient knowledge of the identity, biology and ecology of the insect concerned.

Resistance to insecticides was seen for the first time in 1914 in San Jose scale, *A. perniciosus*, and was the result of the repeated use of lime-sulphur sprays (Broadley 1982). *Heliothis armigera* and *H. punctigera* are two native Australian moth species that have successfully exploited agricultural monocultures of cotton. *H. armigera* developed resistance to DDT in the early 1970s and partial resistance to synthetic pyrethroids in the early 1980's. Resistance was induced through the use of simplistic control strategies that involved regular application of protective broad-spectrum sprays (Zalucki *et al.* 1986). In the case of *I. purchasi*, the cottony-cushion scale, what had been a spectacular example of biological control using imported natural enemies was temporarily interrupted through the ill-conceived use of DDT in 1947 which eliminated the introduced predators (Stern *et al.* 1959). Locusts, in particular *S. gregaria*, provide classic proof of the need to have a sound understanding of the biology and ecology of a pest species. Forecasting future locust plagues and their locations was not possible prior to the elucidation of the role of weather (especially rainfall and wind patterns) in determining fluctuations in hopper populations, in particular the induction of phase changes in solitary hoppers causing them to become gregarious and form plagues (Joern and Gaines 1990).

During the early 1960's applied entomologists and ecologists began to acknowledge that biocidal control had often failed to meet the expectations of economic production, presumably because the pest had been considered in isolation to the production system. This new realisation can be seen in the move away from terms such as "pest control" in favour of the concept of "pest management". Pest management was, according to Geier (1966) "intended to convey the idea of intelligent manipulation of nature for man's lasting benefit". Geier and Clarke (1978/1979) emphasised that pest management advocates should also recognise the needs of society.

Presently there is a trend in Australian forestry (Elliott *et al.* 1990; Ohmart 1990; Stone 1991) and globally (Sagar 1991; Flagler 1992; Saarenmaa 1992; McLean 1994;

Wingfield and Swart 1994; Evans and Fielding 1994; Dahlsten *et al.* 1994; Laranjeiro 1994), to espouse the implementation of Integrated Pest Management (IPM, first conceived by Stern *et al.* 1959) systems for controlling undesirable forest insects. IPM can be seen as a means of accommodating human behaviour and industrial practice making it more acceptable to producers because it considers economic and production constraints, and to the public because environmental and health considerations are appropriately addressed (as emphasised by Geier and Clarke 1978/1979). In order to make appropriate management decisions IPM is heavily reliant upon sound biological information concerning the insect species (Waters and Stark 1980).

This need for basic biological and ecological information as it pertains to potential pest species (e.g. coreid bugs) is supported by authors such as Ohmart (1990) who stated that "To overcome the lack of ecological knowledge of many eucalypt-feeding insects, studies to determine life histories of many species should be encouraged." Likewise, Carne and Taylor (1978) commented that "Far too little is known of the ecology of the insect pests of eucalypt forests to allow the formulation of prescriptions that would guarantee the prevention of losses caused by occasional pest outbreaks." Similarly, Ohmart and Edwards (1991) noted that the increased rate of eucalypt plantation establishment, both in Australia and abroad, and the inevitable development of pest problems within these plantations will "increase pressure for research into insect-eucalypt interactions." Stone (1991) has taken this concept to the point where she recommends that "Entomological input should be an essential component of feasibility studies, and of all stages of planning in future eucalypt plantation programs."

Although the implementation of an IPM system for a given plantation or regrowth forest is an admirable goal, it should be noted that computation of an economic threshold level for such a long rotation "crop" is made very difficult by the uncertainties inherent in such a system (Clarke 1995). Plant (1986) discusses the effect of uncertainty on the estimation of economic threshold levels and notes that it may actually lead to increased pesticide use in some instances. Foremost amongst IPM options for use in forestry would appear to be the use of insect resistant varieties of eucalypt, as proposed by Floyd and Farrow (1994). The use of eucalypt polycultures and the regulation of the size of single species plantations (Carne and Taylor 1978; Abbott 1993) are also possible augmentation options, however, such silvicultural techniques may be less attractive to forest managers. An additional consideration that has the potential to reduce the incidence of insect outbreaks is appropriate site-matching, whether of native or exotic species outside their endemic

habitat ranges, or of eucalypt species with plantation site characteristics (Carne and Taylor 1978; Bain 1981; Elliott *et al.* 1990). All such options will require an advanced knowledge of the ecology of the pest species.

1.6. Thesis Outline.

Three main areas of research were chosen for this thesis. It was considered that these topics would be most likely to answer many of the questions posed at inception and that they could be linked together by the unifying themes of biogeography and host plant utilisation. The three areas chosen were: **(a)** biogeography and seasonal phenologies of *Gelonus*, *Acantholybas* and *Amorbus* (Chapter 4); **(b)** developmental and reproductive biologies (Chapter 5); and **(c)** host plant performance and selection (Chapter 6 and 7). Some additional topics which have received attention during this work are presented as 'stand alone' chapters (Chapters 3 and 8).

The following provides a brief chapter outline, introducing their contents and significance. Each chapter includes it's own review of relevant literature, in the form of an introduction, followed by materials and methods, results and discussion sections.

Chapter 1. Introduction

The intention of this chapter is to briefly introduce the group of insects considered in this thesis, to provide the reader with some background information concerning plantation forestry in Tasmania and Australia and to comment upon the present status of pest management in forestry. It is also intended to detail the reasoning behind the work presented within the thesis so that a logical framework is established for the following chapters.

Chapter 2. General Materials and Methods.

This chapter details the materials and methods which were commonly used throughout this thesis. These techniques are placed together with one another in order to avoid repetition in subsequent chapters.

Chapter 3. Taxonomic Review of the Genera *Gelonus* Stål, *Acantholybas* Breddin and *Amorbus* Dallas (Hemiptera: Coreidae)

As the identities of the species with which one is working is a requisite in biological studies, a summary of the present taxonomic status of the three genera important in the Tasmanian context is presented. Also presented are details of *Amorbus* species not native to Tasmania which were obtained from Australian invertebrate collections. This information is included because it provided the author with a broader perspective of this genus. It must be noted that this chapter is not a full taxonomic revision of the genera

involved. Such an undertaking, although very necessary, was not considered warranted at inception (see chapter 3 for reasons) and was later deemed to be outside the objectives of the project. What is presented is a "working guide" to the species within each genus.

Chapter 4. Biogeography and Seasonal Phenologies of *Gelonus, Acantholybas* and *Amorbus* in Australia

This chapter uses observations made by the author, as well as information obtained from Australian invertebrate collections, to map the geographic distributions of the Tasmanian coreid species within Tasmania and around Australia. Studies of the seasonal phenologies of the Tasmanian species are presented in order to determine the degree of voltinism. The distributions of *Amorbus* species native to the Australian mainland are also presented. Aspects of adult seasonal activity of mainland species, as well as the Tasmanian species on the Australian mainland, were inferred from collection date information.

Chapter 5. Developmental and Reproductive Biologies of *Amorbus obscuricornis* and *Gelonus tasmanicus*

An understanding of the biology of any insect species is heavily reliant upon basic information concerning the type and rate of ontogenesis, be it that of the immature stages or the adults. Hence, I investigated the influence of temperature, photoperiod and humidity on the rates of development of eggs and nymphs of both species, the number of instars in each species (a study which arose as a result of discrepancies in the literature), the seasonality of reproductive behaviour in adults and the survival physiology of overwintering adults.

Chapter 6. Host Plant Performance of *Amorbus obscuricornis* and *Gelonus tasmanicus* on Selected Eucalypt Species

The work in this chapter attempts to discern whether the two species involved exhibit any differences in performance when given no-choice as to the species of eucalypt on which they are placed. Performance was measured in terms of the biological parameters of adult longevity, egg laying capacity and nymphal growth.

Chapter 7. Selection of Eucalypts by *Amorbus obscuricornis* and *Gelonus tasmanicus*

In order to determine what factors influence the selection of eucalypts as hosts by these bugs, records of incidence on hosts in the field were kept throughout the duration of this work. As well as these occurrence records, specific experiments were set-up in order to determine the effect of host plant architecture on selection.

Chapter 8. Defensive Secretions and the Parasitoids, Parasites and Predators of *Amorbus obscuricornis* and *Gelonus tasmanicus*

At the commencement of this work the pungent secretions emitted by these insects attracted my attention and their composition and species/stage differences were

investigated. Also presented are records of various predators, parasites and parasitoids observed to affect both coreid species. In addition, I was particularly interested in the interactions of ants and *A. obscuricornis* which came into close proximity due to the presence of eucalypt manna. The results of these studies are presented in the form of published papers.

Chapter 9. Discussion

This chapter summarises the significant findings made in the research chapters and considers some of the outstanding issues which need resolution in order to better understand both *A. obscuricornis* and *G. tasmanicus*.

In summary, the work presented in this thesis attempts to detail significant features of the biology and ecology of *A. obscuricornis* and *G. tasmanicus*, in particular. It is hoped that this information will provide a source of basic information that forest and plantation managers can refer to when faced with conservation and management issues concerning these arboreal invertebrates. Additionally, the mechanisms of host selection identified for *A. obscuricornis* appear different to those described for many eucalypt herbivores and are of general ecological interest.

Chapter 2

General Materials and Methods

Chapter 2

General Materials and Methods

Introduction

In order to prevent repetition and having to present lengthy materials and methods sections in individual chapters, the following commonly used techniques are described.

2.1. Morphometric and Camera Lucida Techniques.

Morphometric measurements were made using a dissecting binocular microscope fitted with an eye-piece graticule. Specimens used were preserved in alcohol and came from a selection of field sites throughout northern and southern Tasmania, as well as a few laboratory reared insects. The features measured were: apical (IV) antennal segment length, head width across the eyes, pronotum width at the widest point, mid femur length and hind femur length. The results of morphometric examinations of *A. obscuricornis* adults and fifth instar nymphs and *G. tasmanicus* adults are presented in Chapter 3, while measurements taken on nymphs of both species at various stadia are presented in Chapter 5. Line drawings presented in this thesis were prepared using a Wilde camera lucida.

2.2. Field Sampling Technique.

Field sampling of coreids was conducted during the following periods in order to collect seasonal phenology, host plant and behavioural information: 10 March 1992 to 29 May 1992; 19 October 1992 to 22 April 1993; 7 September 1993 to 17 May 1994; 19 August 1994 to 1 March 1995. Regular field sampling was not conducted during winter because bugs were difficult to find during this period. In this thesis the seasons are those of the southern hemisphere, thus: December to February, summer; March to May, autumn; June to August, winter and September to November, spring.

Sampling involved whole tree counts and although eucalypts were the focus of the sampling effort, casual inspections of non-eucalypts were also made to ensure that coreids were not feeding upon other hosts. Trees chosen for sampling were, in the main, less than 165 cm tall. Such trees were chosen primarily because their size and relative canopy simplicity permitted location of the majority of coreids. The size of these "saplings" meant that most of the trees examined were in the vicinity of 1 to 6 years of age and in either juvenile or intermediate foliage. Although a number of field sites were repeatedly visited during the course of this study, no trees were permanently tagged for inspection

(with the exception of those trees utilised in the tree architecture experiment, see Chapter 7). This was thought appropriate given the somewhat variable size of coreid populations across years and thus the potential to waste time sampling set groups of trees at sites which may not have resident coreid populations. On all sampling occassions, the total number of trees examined was recorded whether or not they contained coreids. Following examination, the location, date, weather conditions, the species of *Eucalyptus*, the species of coreid present, their abundance, developmental stage and whether or not the adults were *in copula* was recorded. The seasonal phenology information is presented in Chapter 4, the observations of reproductive behaviour are reported in Chapter 5 and the local distribution and abundance of bugs on different eucalypt species is presented in Chapter 7.

2.3. Coreid Rearing Techniques.

2.3i. Mass Rearing Technique.

Mass cultures of coreids of both species were maintained in six, 90.0 x 39.0 x 39.0 cm, wooden frame cages which were kept in the glasshouse detailed in section 2.3iib. In each cage there were maintained three potted *Eucalyptus regnans* saplings which were watered as required. Cages were emptied and cleaned thoroughly each winter. Insects were kept in these cages to provide eggs and nymphs for developmental rate studies (Chapter 5) and as a source of adults and nymphs for host plant studies (Chapters 6 and 7).

2.3iia. Individual Coreid Rearing Techniques.

Two methods of providing second instar nymphs with plant material were employed, these were:

(a) *use of excised eucalypt shoots kept alive using moist filter paper (Fig. 2.1i)*: This was the first method trialled during the early stages of this project. Small excised eucalypt shoots were placed between moistened filter paper in 9.5 cm diameter covered glass petri dishes. Filter paper discs were moistened every day so long as the shoot appeared healthy. Fresh shoots were placed in glass petri dishes when those within appeared slightly withered. Using this method shoots remained apparently healthy for approximately 3 days. Nymphs reared using this technique were mostly kept individually, however, limited numbers of glass petri dishes occasionally required that nymphs be kept in groups.

(b) *use of single potted eucalypts with specially prepared mesh bags (Fig. 2.1ii)*: Mesh bags with dimensions 23.5 x 47.5 cm were sewn from nylon insect screen to fit over 13

cm diameter pots. In each pot was a single eucalypt which was approximately 1 to 2 years of age. Paper discs, cut so as to surround the tree stem, were used to cover the soil surface, thus aiding location of small nymphs and exuviae. Nymphs reared using this technique were kept individually in order to monitor their growth.

2.3iib. Coreid Rearing Using Controlled Environment and Glasshouse Facilities.

Three controlled temperature environments were employed to rear nymphs. These were:

(a) *four 67.0 x 79.0 x 125.0 cm Contherm™ (Cat 150MCP) controlled temperature/photoperiod cabinets*: These cabinets were illuminated by two 18 W cool white fluorescent tubes and had nominal temperature ranges of 10 to 50°C. Designer specifications cited a temperature fluctuation range of ± 1°C. The light intensity in these cabinets was found to range from 450 lux (middle of cabinet) to 1650 lx (next to fluorescent tube). The light intensity reaching eucalypts inside mesh bags ranged from 300 lx (middle of cabinet) to 1150 lx (next to fluorescent tube). As the light intensity reaching potted eucalypts was not as high as that recorded in the glasshouse, where eucalypts grew well, it was decided to operate these cabinets on a 24 hr photoperiod in an attempt to provide trees with sufficient light. Using separate thermometers to record cabinet temperature it became apparent during experimental work that the in-built temperature display did not match the true temperature readings. For each cabinet the actual temperatures were found to be:

35°C/24 hr light (cabinet 1): 37.67 ± 0.04°C, n = 46 readings at 24 hr intervals,
30°C/24 hr light (cabinet 1): 32.0 ± 0.1°C, n = 59,
28.5°C/24 hr light (cabinet 1): 29.5 ± 0.1°C, n = 12,
25°C/24 hr light (cabinet 1): 26.9 ± 0.1°C, n = 51,
24°C/24 hr light (cabinet 1): 24.9 ± 0.1°C, n = 54,
25°C/0 hr light (cabinet 2): 24.3 ± 0.1°C, n = 81,
20°C/24 hr light (cabinet 2): 19.3 ± 0.1°C, n = 72,
15°C/24 hr light (cabinet 3): 14.8 ± 0.1°C, n = 77,
as above (cabinet 3, experiments 5.2ia and 5.2via, b): 14.3 ± 0.1°C, n = 70,
15°C/0 hr light (cabinet 4): 13.0 ± 0.1°C, n = 76,
11.5°C/24 hr light (cabinet 4): 9.3 ± 0.1°C, n = 82.

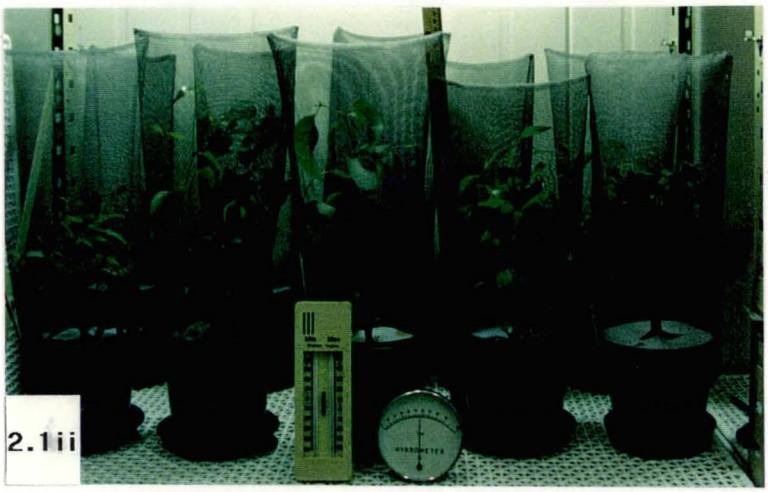
Both of the above methods for supplying plant material to developing nymphs were utilised in these cabinets. Only a few *A. obscuricornis* nymphs were reared through to eclosion in these cabinets and all of these were reared by confining nymphs on whole eucalypts using mesh bags. No nymphs were able to be reared to eclosion on excised

shoot material. No *G. tasmanicus* nymphs were reared to eclosion using any of these techniques. This species was found to be very difficult to rear beyond the second instar under artificial temperature and lighting conditions;

(b) *two controlled temperature/photoperiod rooms*: Rooms were illuminated by fluorescent tubes and a mercury vapour lamp. The temperature in each room was set at 20 and 25°C, respectively. A 16 hr photoperiod was employed during the rearing of nymphs in each of these rooms. Only the mesh bag technique was employed for rearing nymphs in these rooms. The mercury vapour lamp was hung approximately 50 cm above potted eucalypts. The light intensity 50 cm from the base of the mercury vapour lamp was > 3000 lx, whilst, inside a mesh bag at this distance the illumination was 2300 lx. The average temperature and humidity in each room was found to be:
25°C/16 hr light: 27.0°C (n = 20) and 57.4 ± 0.8% relative humidity (n = 69),
20°C/16 hr light: 21.8 ± 0.4°C (n = 18) and 57.8 ± 0.6% relative humidity (n = 68).

No nymphs of either species were reared through to eclosion in either of these rooms. Of the two rooms, nymphal growth advanced furthest in that which was set at 20°C.

(c) *a temperature controlled glasshouse set to operate at 23 ± 3°C*: Photoperiod could not be controlled in this glasshouse so developing nymphs were exposed to ambient photoperiod. Temperature and humidity were recorded using a thermohygrograph. The light intensities inside the glasshouse and a wooden frame cage on a sunny day were > 3000 lx, respectively. Temperature and humidity conditions recorded in the glasshouse during the studies reported in this thesis are presented in Table 2.1. Only the mesh bag technique was employed for rearing nymphs in this glasshouse. Of all the adult *A. obscuricornis* eclosed during the nymphal developmental rate studies, most were reared using potted eucalypts grown under glasshouse conditions. Again, no *G. tasmanicus* nymphs reached eclosion even when given glasshouse grown eucalypts.



Figs 2.1i-2.1iii. Photographs of: **(2.1i)** nymphal rearing of *A. obscuricornis* using excised *E. pulchella* shoots in a controlled temperature cabinet; **(2.1ii)** nymphal rearing using potted *E. regnans* with specially prepared mesh bags in a controlled temperature room; **(2.1iii)** a labelled pair of copulating *G. tasmanicus* adults from glasshouse no-choice experiments.

Table 2.1. Average glasshouse temperature and relative humidity (RH) records. Temperature given in °C, humidity given in percentages. (N.B. temperature regulation was not under automatic computer control during 1992/93. The 1992/93 records were taken at the start of daily observations using a thermometer and a hygrometer as opposed to a thermohygrograph, thus, no maximum and minimum records can be presented. Approximate time these records were taken is given in parentheses. Glasshouse temperature was set to automatically maintain 23 ± 3°C from the start of the 1993/94 season.)

Month	temp. 92/93	RH 92/93	min. temp. 93/94	max. temp. 93/94	min. RH 93/94	max. RH 93/94	min. temp. 94/95	max. temp. 94/95	min. RH 94/95	max. RH 94/95
Sep.	-	-	-	-	-	-	18.0	22.9	44.5	56.7
Oct.	-	-	16.0	25.8	60.2	75.3	18.9	23.6	54.2	73.3
Nov.	23.3 (1621)	47.4 (1621)	18.6	24.9	61.5	73.0	18.9	23.5	58.7	81.8
Dec.	23.5 (1654)	55.3 (1654)	20.0	26.3	65.2	83.5	19.5	24.7	60.3	84.8
Jan.	23.5 (1642)	55.3 (1642)	19.0	25.9	50.2	69.7	19.7	24.3	65.8	86.4
Feb.	24.2 (1654)	54.1 (1654)	21.6	26.1	51.0	71.0	19.7	24.6	64.0	86.1
Mar.	22.2 (1727)	59.0 (1727)	19.1	25.2	49.2	67.9	19.5	24.3	61.1	83.8
Apr.	20.8 (1628)	63.2 (1628)	18.7	25.2	48.0	67.4	-	-	-	-
May	20.5 (1558)	57.2 (1558)	-	-	-	-	-	-	-	-
Jun.	19.5 (1601)	51.4 (1601)	-	-	-	-	-	-	-	-
Jul.	21.5 (1618)	61.6 (1618)	-	-	-	-	-	-	-	-
Aug.	23.1 (1602)	58.5 (1602)	-	-	-	-	-	-	-	-
Sep.	22.2 (1621)	62.9 (1621)	-	-	-	-	-	-	-	-
average	22.2	56.9	19.0	25.6	55.0	72.5	19.2	24.0	58.4	79.0

2.4. Eucalypt Potting Mixture and Maintenance.

Eucalypt seedlings which were approximately 1 year old were purchased from Pulchella Nursery, Buckland, and/or Plants of Tasmania, Ridgeway. Some additional eucalypts were also obtained from the Plant Science and Agricultural Science Departments, University of Tasmania. The availability of seedling eucalypts at these nurseries determined the species used in experiments. Following purchase, most trees were pruned to about 40 cm in height and transferred to 13 cm diameter black plastic pots containing eucalypt mix. Trees were grown in a specially prepared eucalypt potting mix which comprised 8 parts hammer-milled/composted pine bark, 2 parts coarse river sand, 1 part peat with the following nutrients added at the time of preparation: Osmocote® (low phosphorus)/dolomite lime/chelated iron/Micromax®. Trees were kept in a shadehouse for some months prior to commencing experiments in order to allow establishment. Whilst in the shadehouse they were watered daily.

2.5. Coreid Dissection Technique.

Dissections of adult coreids were undertaken to visually appraise fat contents, numbers of eggs (see Chapter 5) and to search for internal parasites (see Chapter 8). Insects were killed using ethyl acetate and/or freezing. The insect's hemelytra and wings were then unfolded and removed to reveal the dorsal tergites. After the dorsal tergites were cut away with a scalpel a visual appraisal of the fat body was made. The amount of fat present was assessed as either low, medium or high (occasionally intermediate categories were used where appropriate) as a means of validating the quantitative estimates obtained using chloroform extraction (see Chapter 5). In addition, the number of eggs apparent was recorded. Given that each female has two ovaries, each comprising seven ovarioles (Kumar 1965), it was decided to only count those eggs at an advanced stage of oogenesis. Following visual appraisal of fat content and enumeration of eggs in females the abdominal cavity and internal organs were thoroughly examined under the dissecting microscope for internal parasites as per Beard (1940, p. 640).

2.6. Coreid Handling and Labelling Techniques.

Eggs and nymphs were handled using cardboard tweezers as per Steinbauer and Wardhaugh (1995). Nymphs were gently held by the apical antennal segment.

In order to help identify specific adults used in the no-choice host plant performance experiments (detailed in Chapter 6), small, numbered plastic labels of differing colour were utilised. Labels were supplied by John L. Guilfoyle Pty. Ltd. and are employed

normally to label queen bees. In order to attach these labels, adults were anaesthetised using diethyl ether and the labels attached to the top of the pronotum using the adhesive provided (Fig. 2.1iii).

2.7. Datalogger Installation.

Two dataloggers were used at field sites in the plant architecture experiment detailed in Chapter 7. The dataloggers employed were "Starlog" Portable Dataloggers (model 6003A), with version 2.02 software, produced by Unidata Australia. Each datalogger was fitted with a model 6501EU ambient temperature and relative humidity sensor and model 6515AD590 temperature probe. Dataloggers were affixed to steel poles, which had been cemented into place, at breast height (approximately 1.3 m). The cables to the temperature probes were protected from chewing animals using Clipsal 20 mm medium duty corrugated conduit. In addition, a Nylex Gardena™ Rain Gauge 600 was attached to each datalogger housing to collect rainfall which was recorded weekly.

2.8. Water, Nitrogen and Carbon Analyses.

The nutritional status of eucalypt shoots was assessed for work detailed in Chapters 6 and 7. In all instances eucalypt shoots taken were entire and comprised the apical bud and the first expanded leaf (for *E. obliqua*, *E. regnans*, *E. delegatensis* and *E. ovata*) or the first pair of expanded leaves (for *E. globulus*, *E. viminalis*, *E. coccifera*, *E. tenuiramis*, *E. pulchella* and *E. amygdalina*). Following removal, shoots were immediately placed into a plastic bag and kept on ice packs in a small insulated container prior to their return to the laboratory. In the laboratory the fresh weight of shoots was obtained before placing them into labelled brown paper bags. Bags containing shoots were then air dried at 40°C for one week before being re-weighed and ground into a fine powder using a mortar and pestle. The water content of shoot samples was then calculated. Ground shoot samples were then placed into glass vials with screw cap lids and taken to Dr Graham Rowbottom, Central Science Laboratory, University of Tasmania, for nitrogen and carbon analysis. Total N and C contents of samples was determined using a (Carlo Erba) CHNS-O EA1108-Elemental Analyzer. Samples were checked against known reference standards following each analysis. Results are presented as total percentage composition.

2.9. Leaf Toughness Studies.

Leaf toughness measurements were taken on experimental trees in the plant architecture experiment detailed in Chapter 7. It was originally hoped that stem toughness just beneath the apical bud could be measured, however, leaf toughness of the first expanded leaf

away from the apical bud was actually recorded. Stem toughness was originally chosen because *A. obscuricornis* was known to feed at this site, whereas *G. tasmanicus* was known to feed on petioles, leaves and stems (both young and old). During initial trials it was found that stem toughness could not be reliably measured because the stem diameters of various eucalypt species varied so widely. Thus, although stem toughness could be measured on eucalypts with thick stems (e.g. *E. globulus*) it was difficult to take measurements for species with very thin stems (e.g. *E. pulchella* and *E. amygdalina* in particular). On species with thin stems the penetrometer frequently slipped off and/or crushed the stem.

Leaf toughness was measured using either a Chatillon AG-150 (capacity 150 x 5 g) or AG-50 (capacity 50 x 1 g) Dial Tension gauge (as per Sands and Brancatini 1991). The gauge used depended upon the toughness of the leaf. The probe which was attached to each gauge had a surface area of 0.0314 mm^2. Measurements were taken in the middle of the leaf lamella with one measurement per leaf. A total of 10 measurements was taken per eucalypt species. Measurements were adjusted in accordance with the gauge's calibration. Weights were transformed into $\log_{10}$ form for homogeneity of variance before statistical analysis, as per Lowman and Box (1983). Results are presented as g mm^{-2}.

Chapter 3

Taxonomic Review of the Genera *Gelonus* Stål, *Acantholybas* Breddin and *Amorbus* Dallas (Hemiptera: Coreidae)

Chapter 3

Taxonomic Review of the Genera *Gelonus* Stål, *Acantholybas* Breddin and *Amorbus* Dallas (Hemiptera: Coreidae)

3.1. *Introduction*

3.1i. The Genera *Gelonus*, *Acantholybas* and *Amorbus*.

According to Semmens *et al.* (1992) there are 5 species of Tasmanian Coreidae, namely *Gelonus tasmanicus*, *Acantholybas kirkaldyi*, *Amorbus angustior*, *A. obscuricornis* and *A. rubiginosus*. It was this record of three species of *Amorbus* in Tasmania which was the initial catalyst for undertaking this review of the taxonomy of the Tasmanian coreid genera. That is, it was necessary to be certain of the identity of the species whose biology and ecology was to be studied. In order to resolve this issue it was decided to undertake a morphometric analysis of *Amorbus* specimens then available and to examine specimens from other Tasmanian and Australian collections. In relation to the latter study, it was thought that an overview of all the species of *Amorbus* would provide a better appreciation of the relative significance of selected morphological features in separating species.

The need to resolve these local taxonomic problems provided a unique opportunity to tackle a much larger problem. That is, none of these three genera has been the subject of a specific taxonomic revision and so much confusion surrounds aspects of species level nomenclature (particularly for *Amorbus*) and the higher classification of groups (particularly for *Acantholybas* and the tribe Colpurini).

The results are presented in alphabetical order for each of the species in the genera *Gelonus*, *Acantholybas* and *Amorbus*. As this is the first such taxonomic and photographic compilation it is hoped that this information can be employed to determine the identity and sex of any given species within these genera.

3.2. *Materials and Methods*

3.2i. Morphometric Study of *Amorbus* Adults from Tasmania.

The aim of this study was to determine the number of *Amorbus* species present in Tasmania. Principal Component Analysis (PCA) was employed to investigate whether morphometric data from a selection of *Amorbus* adults could have originated from one or more unique populations. Details concerning the specimens used and measurements taken are presented in Chapter 2.

3.2ii. Description Translations.

In order to assist species identification original descriptions, where not written in English, were translated and are presented in Appendix 1 as literal translations of the printed text (i.e. they are presented in a style and format which closely resemble that in which they were originally written). Latin and French descriptions were translated into English by Dr Peter Davis (University of Tasmania) and German descriptions by Mr Wolfgang Spielmeyer (University of Tasmania).

3.2iii. Type Specimens.

The following type specimens were examined: *G. tasmanicus* ♀ lectotype; *A. affinis* ♂ and 2 ♀ syntypes; *A. angustior* ♂ holotype; *A. bispinus* ♂ and 2 ♀ syntypes; *A. obscuricornis* ♂ and ♀ syntypes; *A. rhombeus* ♂ holotype; *A. rhombifer* ♂ holotype; *A. robustus* ♀ holotype; *A. rubicundus* ♀ allotype; *A. subserratus* ♂ holotype; *A. brunneus* ♀ lectotype (here designated) and ♂ paralectotype (here designated); *A. longulus* ♂ holotype. A list of all specimens examined can be found in Appendix 2.

3.2iv. Light Microscopy and Photography.

Specimens were photographed using one or other of the following microscope/camera combinations: an Asahi Pentax Spotmatic 35 mm single reflex camera attached to a SZ-PT Olympus dissecting microscope (illumination from two goose-neck light sources) fitted with a Hoya 80B filter; a Nikon FX-35 camera with a Nikon AFX electronic exposure meter attached to a Nikon SMZ-10 dissecting microscope (illumination from a ring light source) fitted with a Hoya 80B filter; a Minolta X-700 camera mounted to a Zeiss Stemi 2000-C dissecting miscroscope with Microlight 150 ring light source. To provide continuity of comparison only male specimens were photographed where possible. Composition of each photograph was determined by morphological feature being portrayed, size of specimen and presentation.

3.2v. Scanning Electron Microscopy (SEM).

The primary aim of this study was to determine whether any significant morphological differences were apparent between specimens of "*A. obscuricornis* Tasmania" and "*A. obscuricornis* mainland". To this end the following morphological features were examined: antennal segment IV, apex of rostrum and the maculae of hind femora. For the purposes of these studies features from the following specimens were examined:

A. obscuricornis: ♂ Ridgeway, Tas., 15/3/1994 (MJS); ♂ Brooks Bay, Tas., 18/3/1993 (MJS); ♂ Darcy Link Rd./Brooks Bay, Tas., 12/4/1994 (MJS); ♀ Ridgeway, Tas., 15/3/1994 (MJS); ♀ Darcy Link Rd./Brooks Bay, Tas., 12/4/1994 (x2) (MJS); ♂ Mt. Kosciusko, N.S.W., 24/11/1952 (BCRI); ♂ Black Mt., A.C.T., 30/11/1972 (ANIC); ♂ Pilot Hill, N.S.W., 21/2/1981 (ANIC).

SEM work was conducted in collaboration with Mr W. Jablonski of the Central Science Laboratory (CSL), University of Tasmania. The microscope used was an Environmental SEM System 2020 (ElectroScan Corp. (U.S.A.)).

3.2vi. Dissection and Illustration of Parameres.

The aim of this study was to determine whether any significant morphological differences were apparent between the parameres of specimens of "*A. obscuricornis* Tasmania" and "*A. obscuricornis* mainland". Pinned specimens were softened by placing above water overnight and genital capsules then removed by gently squeezing the tip of the abdomen with a pair of forceps until the capsule was freed. Parameres were then dissected from the genital capsule in a saline bath under the dissecting microscope. Parameres from the following specimens were examined:

A. obscuricornis: ♂ Ridgeway, Tas., 15/3/1994 (MJS); ♂ Brooks Bay, Tas., 18/3/1993 (MJS); ♂ Darcy Link Rd., Tas., 21/4/1994 (MJS); ♂ Mt. Kosciusko, N.S.W., 17/12/1953 (BCRI); ♂ Hampton, N.S.W., 27/12/1968 (BCRI); ♂ Jenolan State Forest, N.S.W., 29/12/1968 (BCRI).

Following dissection, parameres were illustrated using a camera lucida by Mrs Kathy McQuillan. Genital capsules of *Acantholybas* species were also illustrated by Mrs Kathy McQuillan.

3.2vii. Institutions.

Material was requested from Australian and International collections. Abbreviations as used in the text and Appendix 2 are: MJS, personal collection of the author; MP, Muséum d'Histoire Naturelle, Paris; NMW, Naturhistorisches Museum Wien; DEI, Deutsches Entomologisches Institut, Eberswalde; BZM, Bogor Zoological Museum,

Indonesia; IBUNAM, Instituto de Biología Universidad Nacional Autonoma de Mexico, Mexico City, Mexico; HEC, Hope Entomological Collections, University of Oxford, U.K.; SBS, School of Biological Sciences, University of Auckland, New Zealand; ANIC, Australian National Insect Collection, CSIRO, Canberra; QM, Queensland Museum, Brisbane; MV, Museum of Victoria, Abbotsford; SAM, South Australian Museum, Adelaide; WAM, Western Australian Museum, Perth; DPIQ, Department of Primary Industries Queensland, Indooroopilly; DPIFNT, Department of Primary Industry and Fisheries Northern Territory, Darwin; WADA Western Australian Department of Agriculture, South Perth; NRLSA, Northfield Research Laboratories South Australia, Adelaide; WAITE, Waite Agricultural Research Institute, University of Adelaide, Glen Osmond; UQIC, University of Queensland Insect Collection, Brisbane; BCRI, Biological and Chemical Research Institute, Rydalmere; FCNSW, Forestry Commission of N.S.W., West Pennant Hills; VAIC, Victorian Agricultural Insect Collection, Burnley; QVM, Queen Victoria Museum, Launceston; TDPIF, Tasmanian Department of Primary Industry and Fisheries, New Town; TM, Tasmanian Museum, Hobart; FT, Forestry Tasmania, Hobart; DASUT, Department of Agricultural Science, University of Tasmania, Sandy Bay.

3.3. *Results*

3.3i. Morphometric Study of *Amorbus* Adults from Tasmania.

The PCA analysis of *Amorbus* adults demonstrated that only one group of individuals was represented. The first two principle components explained 94.2% of the variation in the data. When sex was used as a variable the results clearly separated into two distinct groups of individuals and the first two principle components explained 91.1% of the variation (Fig. 3.1). It was concluded that morphometric analysis did not suggest the presence of cryptic groups.

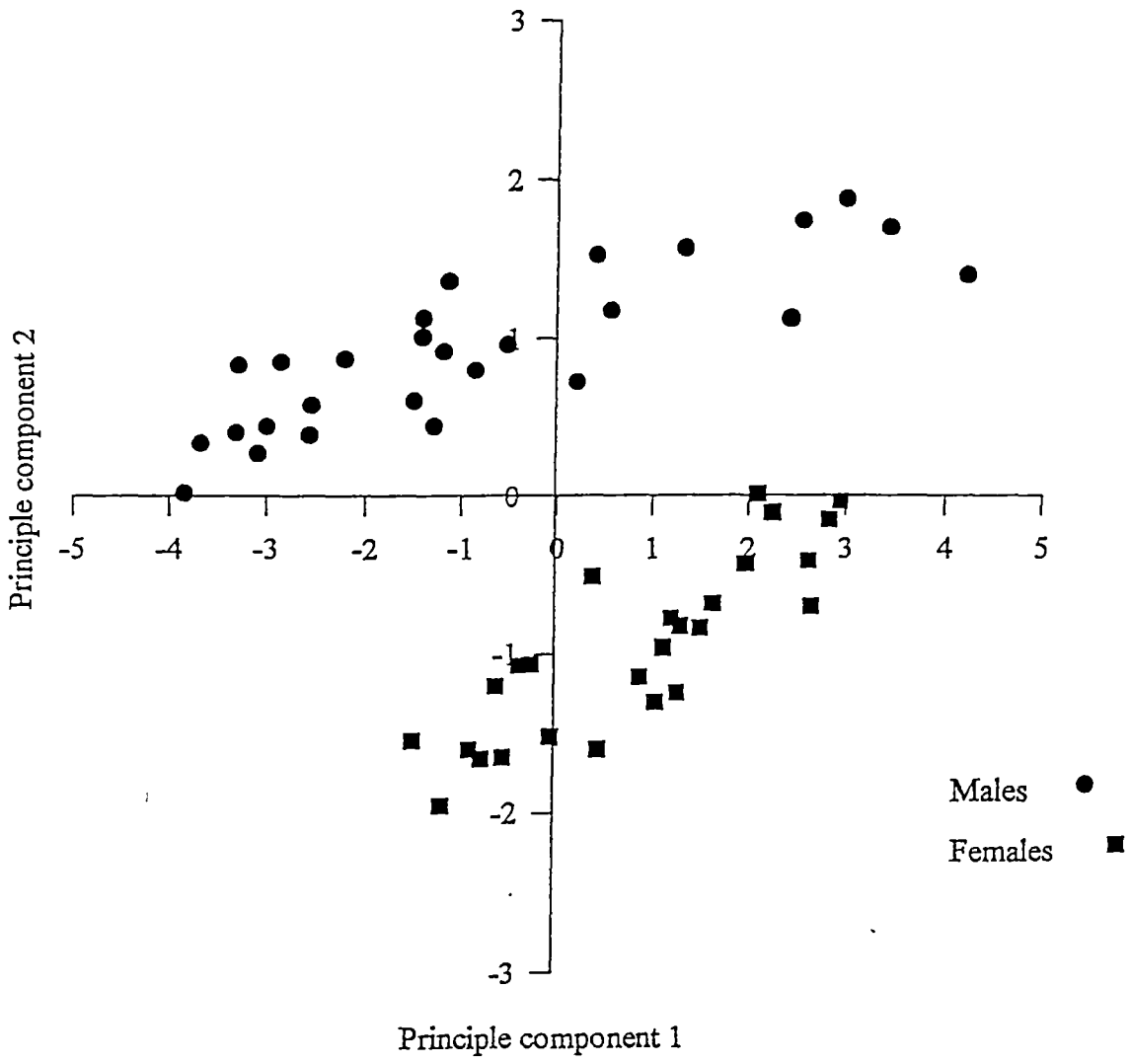


Fig. 3.1. Plot of principal component 1 versus principal component 2 for *Amorbus* adults from Tasmania.

3.3ii. Taxonomic Studies.

3.3iia. *Gelonus* Stål.

Gelonus Stål (1865) «key to the subfamily "Coreida", in Latin»; *Gelonus* Stål (1873) «key to the division "Amorbaria", in Latin, and listing».

Genus diagnosis

Antenniferous tubercles absent; bucculae present; anterior lateral margins of pronotum with small tubercles; hind femora not incrassate, armed with a single spine distally; tibiae slender; macropterous.

Genus re-description

See description of *G. tasmanicus*.

Genus notes

Presently, the genus *Gelonus* is thought to consist of only one species. Morrow (1977b), however, mentioned collecting what was thought to be a second *Gelonus* species from *Eucalyptus perriniana* and *E. pauciflora* near "Dainer's Gap" (elevation 1585 m) in the Mt. Kosciusko National Park (35°12'S 148°43'E), New South Wales. *G. tasmanicus* is a dark, almost black, species, intermediate in body length between species of *Acantholybas* and *Amorbus*.

#1 *Gelonus tasmanicus* (Le Guillou)

Syromastes tasmanicus Le Guillou (1841) «Latin description»; *Amorbus discolor* Dallas (1852) «Latin and English descriptions, respectively»; *Gelonus discolor* Walker (1871) «listing only»; *G. tasmanicus* Stål (1873) «listing and confirmation of synonymy with *Syromastes tasmanicus* Le Guillou and *Amorbus discolor* Dallas»; *Gelonius tasmanicus* Shaefer (1965) (*Gelonius* in error) «conjunctival description».

Number of specimens examined: 440 (Appendix 2).

Re-description

Head (Figs 3.2i, 3.2ii, 3.3ii): Rostrum reaching beyond posterior margin of prothorax in ♂♂, slightly longer in ♀♀. Antennae with dark bands at the distal ¼ of segment II, distal ¾ of segment III and distal ¾ of segment IV; with luteous bands at proximal ¼ of segment III, distal ¼ of segment III and proximal ¼ of segment IV. Head without antenniferous tubercles.

Thorax (Figs 3.2i, 3.2ii, 3.3i): Hind femora of both sexes not swollen but armed with a distal spine; hind tibiae un-armed; luteous maculae absent. Evaporatorium with a slightly

elevated rim, not concolourous with surrounding thorax in ♂♂, but mostly concolourous in ♀♀. Scutellum with a luteous spot posteriorly. Hemelytra not surpassing apex of abdomen and each with a central luteous spot.

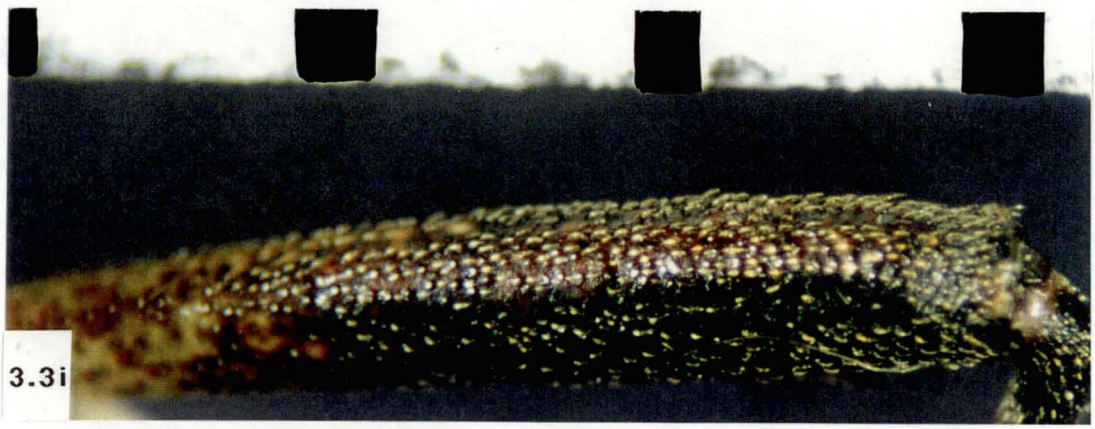
Abdomen (Figs 3.2i, 3.2ii, 3.4i-3.4ii(♂), 3.4iii-3.4iv(♀)): Posterior and anterior margins of connexivum with luteous margins forming approximately 6 distinct bands when viewed dorsally. Abdominal sternite 7 (VIIS) with 2 trichobothrial tubercles on each side, VIS with 3, VS with 3, IVS with 3 and IIIS with 3.

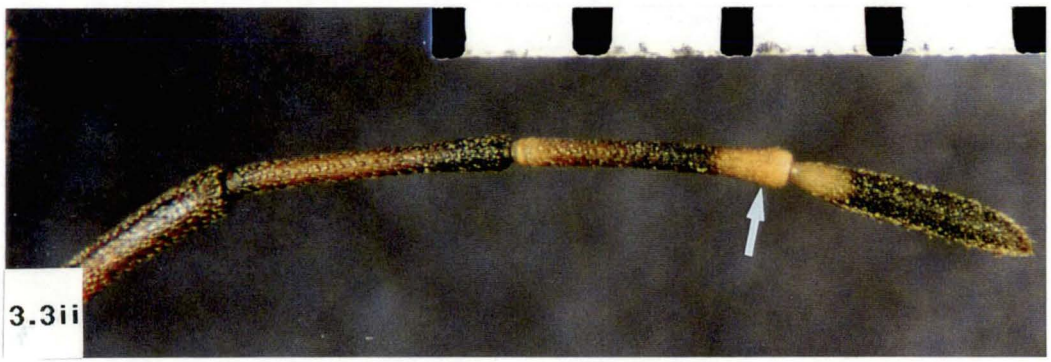
Species notes. *G. tasmanicus* is a darker coloured species than either *Acantholybas* or *Amorbus*. Dorsally, the body shape of this species is slender (especially in ♂♂) and laterally is less dorsoventrally pronounced than *Acantholybas*. The trichobothria are also not as prominent as those of *Acantholybas*. The size of various morphological features for this species are given in Table 3.1.

Table 3.1. Summary of morphological features of *Gelonus tasmanicus* adults (measurements in mm). Ranges given in parentheses.

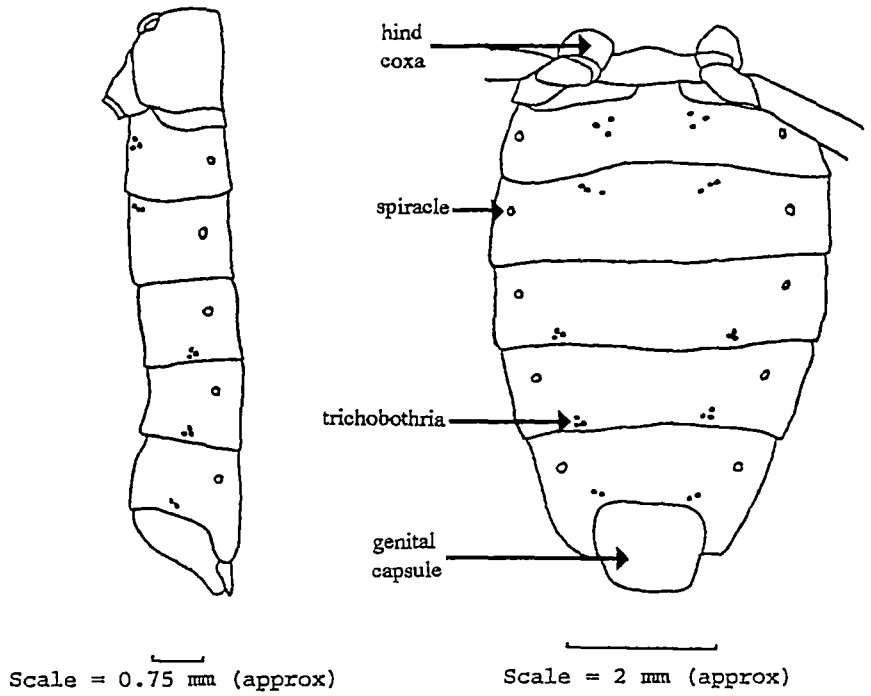
Feature	Adult ♂♂ mean ± se [n]	Adult ♀♀ mean ± se [n]
apical antennal length	1.88 ± 0.02 [18] (1.70-2.05)	1.86 ± 0.02 [21] (1.65-2.00)
head width	1.78 ± 0.01 [18] (1.70-1.90)	1.85 ± 0.01 [22] (1.75-2.00)
pronotum width	3.77 ± 0.06 [18] (3.30-4.30)	4.49 ± 0.05 [22] (3.75-4.80)
mid femur length	3.71 ± 0.04 [17] (3.50-4.10)	3.86 ± 0.04 [22] (3.50-4.20)
hind femur length	4.70 ± 0.04 [17] (4.40-5.00)	4.97 ± 0.04 [22] (4.65-5.40)

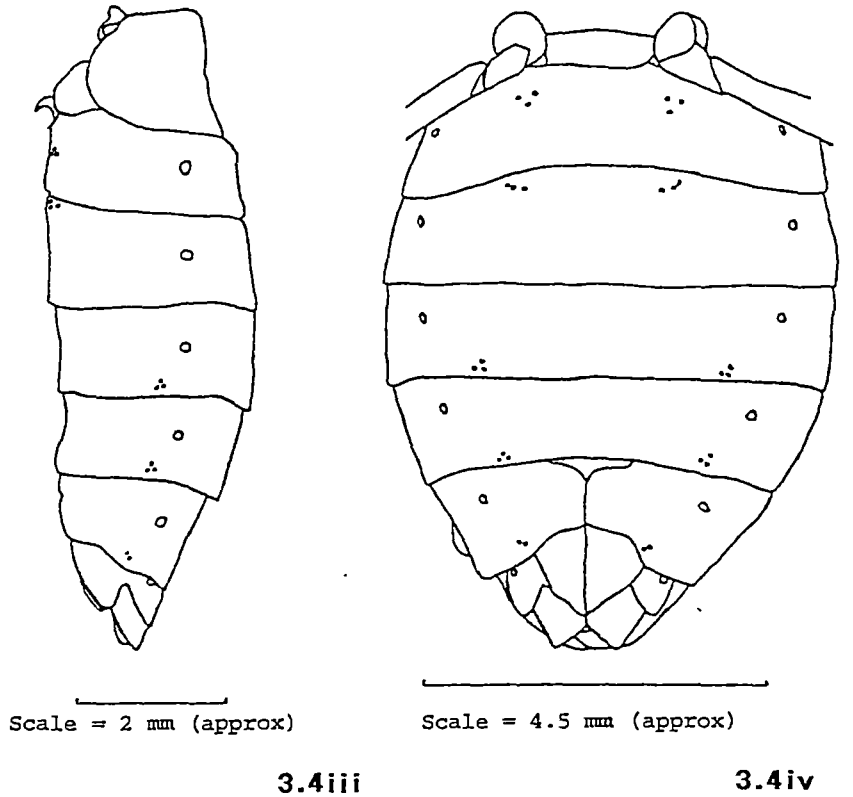
Figs 3.2i, 3.2ii. *G. tasmanicus*, adult ♂: **(3.2i)** dorsal view (luteous bands on connexivum and spot on hemelytron and scutellum highlighted by arrows); **(3.2ii)** lateral view (luteous evaporatorium highlighted by arrow). (Scale line interval = 1 mm.)





Figs 3.3i, 3.3ii. *G. tasmanicus*, adult ♂: **(3.3i)** hind femur, dorsal view; **(3.3ii)** antenna, dorsal view (a luteous region highlighted by arrow). (Scale line interval = 1 mm.)





Figs 3.4i-3.4iv. *G. tasmanicus*: **(3.4i)** abdomen of adult ♂, lateral aspect; **(3.4ii)** abdomen of adult ♂, ventral aspect; **(3.4iii)** abdomen of adult ♀, lateral aspect; **(3.4iv)** abdomen of adult ♀, ventral aspect.

3.3iib. *Acantholybas* Breddin.

Acantholybas Breddin (1899) «genus description, in Latin»; *Acanthocolpura* = *Acantholybas* Breddin (1900b) «synonymy confirmed».

Genus diagnosis

Antenniferous tubercles armed with spines; bucculae developed; anterior lateral margins of pronotum with tubercles; hind femora not incrassate and unarmed; tibiae slender; macropterous.

Genus re-description

Head. Rostrum long, reaching abdomen. Antenniferous tubercles spined; distinct, swollen, region posterior to each eye dorsally. Bucculae well developed. First antennal segment distinctly swollen.

Thorax. Anterior margins of pronotum produced into tubercles. Scent gland opening swollen, evaporatorium mostly concolourous with surrounding thorax. Hind femora not sexually dimorphic. Femora non-incrassate, unarmed; tibiae slender.

Abdomen. Sternites beneath fourth rostral segment sulcate. Abdomen dorsoventrally enlarged with well developed trichobothria which are usually sunk in small depressions; trichobothria located medially on sterna IIIS and IVS, laterally on sterna VS, VIS and VIIS. Posterolateral margins of connexivum marked with dorsal luteous bands.

Genus notes

The genus *Acantholybas* Breddin (Coreidae: tribe Colpurini) is one of approximately 19 genera within the tribe Colpurini (Schuh and Slater 1995). Schaefer (1964) considered that *Acantholybas* represented a primitive but specialised group of the Coreidae. Most species closely related to this genus are dark brown, often with yellow mottling (Dolling 1987).

Breddin (1899) described *Acantholybas* for the species *A. longulus*. *A. brunneus* (Breddin 1900a) and *A. kirkaldyi* (Bergroth 1909) complete the genus. Much confusion has surrounded the subfamily and tribal placements of *Acantholybas*. For example, in quoting W.E. China, Woodward (1951, 1961) ascribed *A. brunneus* to the subfamily Coreinae, tribe Hygiini. Kumar (1965) raised the tribe Colpurini (first proposed by Distant 1902, see Schaefer 1965) to subfamily rank (after Štys 1964) and therein referred to it as the Colpurinae (= Hygiinae = Lybantinae = Pachycephalinae, Štys 1964). Based on the work of Ahmad (1970), Schuh and Slater (1995) consider that the tribe Colpurini also

merits subfamily status. Schaefer (1965) placed *Acantholybas* in the unique '*Acantholybas*-group (Coreinae)', but considered *Acantholybas* to be more closely related to the Pseudophloeinae than the Coreinae. According to Dolling (1987) this *Acantholybas*-group was of equivalent subfamily rank to the other subfamilies of the Coreidae. Presently, species of colpurine are usually placed in the Coreinae, tribe Colpurini (Semmens *et al.* 1992; Brailovsky 1994; Schuh and Slater 1995).

Very little is known about the members of *Acantholybas* (Brailovsky 1993). These insects are thought to live beneath low plants, among decaying plant material and other such habitats (Dolling 1987; Brailovsky 1993; Woodward 1951). Maschwitz and Klinger (1974) and Maschwitz *et al.* (1987) reported finding the colpurine *Hygia cliens* Dolling in a trophobiotic relationship with the ant, *Meranoplus mucronatus* F. Smith (Hymenoptera: Formicidae). Bugs were found to secrete a fluid containing glucose which the ants ingested and the ants attacked objects brought into the vicinity of the bugs. Descriptions of such mutualisms, common among the Sternorrhyncha and Auchenorrhyncha, are rare among the Heteroptera and deserve further study.

Key to species of *Acantholybas*

Males

1. Rostrum long, reaching posterior margin of fifth abdominal sternite; scutellum wider than long; head with a faintly luteous, longitudinal, stripe; fore femora entirely grey in colour, hind femora mottled; body grey/black in colour; antenniferous tubercles acute and very prominent; body > 10 mm long; Tasmania ..... *A. kirkaldyi* Bergroth
   Rostrum reaching posterior margin of fourth abdominal sternite; scutellum longer than wide; coloration of head, femora and body not as above; antenniferous tubercles less prominant; body ≤ 10 mm long; non Tasmanian ..... 2.
2. Head with distinct, luteous, longitudinal stripe; femora all mottled; New South Wales, south-east Queensland and New Zealand ..... *A. brunneus* (Breddin)
   Head without distinct, luteous, longitudinal stripe; hind femora only mottled; Lombok Island, Indonesia ..... *A. longulus* Breddin

Linear body measurements of type material were made using an eye-piece micrometer mounted in a Kyowa microscope. Measurements in Table 3.2 are given in millimeters. Terminology used follows that of Brailovsky (1993). A revision of the genus is given by: Steinbauer, M.J. and Clarke, A.R. (In review). *Ann. Ent. Soc. Am.* (thesis back pocket).

#1 *Acantholybas brunneus* (Breddin)

Acanthocolpura brunnea Breddin (1900a) «Latin description»; *Acantholybas brunneus* Bergroth (1909) «comparison of *A. kirkaldyi* and *A. brunneus*, in Latin»; *A. brunneus* Woodward (1951) «collection records, adult and nymphal descriptions», Woodward (1953) «collection records, notes on biology», *A. brunneo* (in error) Woodward (1961) «key to New Zealand Coreidae, terminalia and egg decriptions»; *A. brunneus* Wise (1958a) «host plant records», Wise (1958b) «host plant records»; *A. brunneus* Schaefer (1965) «conjunctival description, paramere illustration, discussion of classification status»; *A. brunneus* Brailovsky (1993) «diagnosis, paramere illustration, distribution listed».

Number of specimens examined: 29 (Appendix 2).

Re-description

Head (Figs 3.5i, 3.6i, 3.7i): Brown above, with distinct luteous, longitudinal, stripe. Antenniferous tubercles armed with small spines. Rostrum reaching posterior end of fourth abdominal sternite in males, anterior end in females. Apex of first rostral segment reaching anterior border of prosternum, apex of second terminating above mesosternum, apex of third reaching anterior edge of metasternum. Bucculae well developed. Juga narrow, well developed; tylus slightly acuminate. Antennal segment I protuding beyond head by more than half its length, antennal segment II longest, followed by IV, III and I; distal half antennal segment IV yellowish, remainder brown. Joints between antennal segments I/II and II/III yellowish.

Thorax (Figs 3.5i, 3.6i): Scutellum length approximately equal to width, with pale yellowish spot posteriorly. Lateral margins of pronotum not raised, culminating in small apical tubercles anteriorly. Evaporatorium brownish in colour, mostly concolorous with surrounding thorax except for a small yellowish spot anteriorly. All femora mottled. Hemelytra not reaching apex of abdomen, not covered with opaque membrane in male.

Abdomen (Figs 3.5i, 3.6i, 3.8i-3.8ii(♂), 3.9i-3.9ii(♀)): Trichobothrial areas apparent laterally, those of abdominal sternite VIIS with 2 tubercles on each side, VIS with 3, VS with 3, IVS with 3 and IIIS with 3. Venter brownish and variegated in colour. Approximately six yellowish bands on posterior margins of connexivum.

Measurements: see Table 3.2.

Species notes. *A. brunneus* is the smallest species in the genus.

#2 *Acantholybas kirkaldyi* Bergroth

Acantholybas kirkaldyi Bergroth (1909) «Latin description»; Woodward (1951) «listed,

known distribution cited»; Semmens *et al.* (1992) «listed»; Brailovsky (1993) «comparison with *A. brunneus* and known distribution cited».

Number of specimens examined: 2 (Appendix 2).

Re-description

Head (Figs 3.5ii, 3.6ii, 3.7ii): Blackish above, with a faint luteous, longitudinal, stripe. Antenniferous tubercles armed with prominent spines. Rostrum long, reaching posterior end of fifth abdominal sternite in male, anterior end in female. Apex of first rostral segment reaching anterior border of prosternum, apex of second near middle of midcoxae, third rostral segment reaching third abdominal sternite. Bucculae very prominent. Juga narrow and well developed; tylus rounded. Antennal segment I protruding beyond head by more than half its length, antennal segments II and IV longest, followed by III and I; joints between antennal segments II/III and III/IV reddish in colour. Distal three-quarters of antennal segment IV pale brown, remainder blackish.

Thorax (Figs 3.5ii, 3.6ii): Scutellum wider than long, with pale yellowish spot posteriorly. Lateral margins of pronotum erect, culminating in apical tubercles anteriorly. Evaporatorium mostly concolourous with surrounding thorax except for a yellowish spot anteriorly. Fore femora entirely grey, mid femora with a small luteous portion near coxae and hind femora mottled. Hemelytra reaching apex of abdomen, covered with opaque membrane in male.

Abdomen (Figs 3.5ii, 3.6ii, 3.8iii-3.8iv(♂), 3.9iii-3.9iv(♀)): Trichobothrial areas apparent laterally, those of abdominal sternite VIIS with 2 tubercles on each side, VIS with 3, VS with 3, IVS with 3 and IIIS with 3. Venter blackish and variegated in colour. Four to five diffuse, pale yellow bands at posterior margins of the connexival segments (less distinct than those of *A. brunneus*).

Measurements: see Table 3.2.

Species notes. *A. kirkaldyi* is considerably larger (live body weight ♂ 35.4 mg (n=1) and ♀ 57.0 mg (n=1)) than either *A. brunneus* or *A. longulus*.

#3 *Acantholybas longulus* Breddin

A. longulus Breddin (1899) «Latin description»; Breddin (1900b) «key to the genera of the tribe Pachycephalini, Latin description»; *A. longulus* Woodward (1951) «listed».

Number of specimens examined: 1 (Appendix 2).

Re-description

Head (Figs 3.5iii, 3.6iii, 3.7iii): Brown above, without a luteous, longitudinal stripe.

Antenniferous tubercles armed with small spines. Rostrum long, reaching posterior margin of fourth abdominal sternite. Apex of first rostral segment reaching anterior of prosternum, apex of second reaching middle of mesosternum, apex of third segment reaching anterior of third abdominal sterna. Bucculae well developed. Juga narrow, well developed; tylus somewhat acuminate. Antennal segment I protuding beyond head by more than half its length, antennal segment II longer than I, III and IV missing.

Thorax (Figs 3.5iii, 3.6iii): Scutellum longer than wide, with pale yellow spot posteriorly. Lateral margins of pronotum not raised, culminating in small apical tubercles anteriorly. Evaporatorium concolourous with surrounding thorax except for very small, luteous spot anteriorly. Fore femora grey, mid femora with small luteous portion near coxae, hind femora mottled. Hemelytra reaching apex of abdomen; hemelytral membrane distinctly darker than rest of hemelytra.

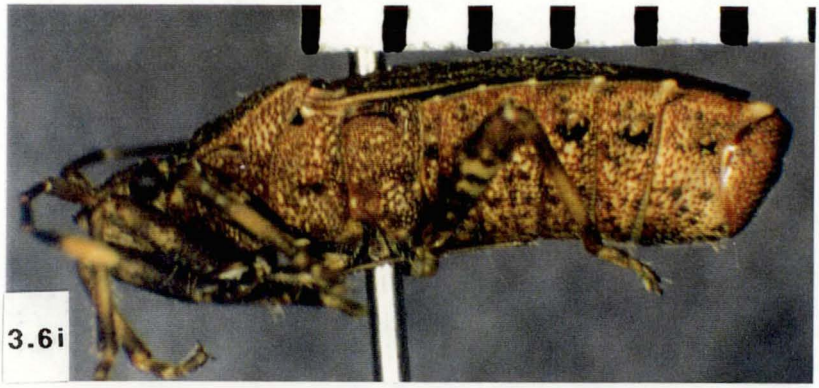
Abdomen (Figs 3.5iii, 3.6iii, 3.8v(♂), 3.8vi(♂)): Trichobothrial areas apparent laterally, those of abdominal sternite VIIS with 2 tubercles on each side, VIS with 3, VS with 3, IVS with 3 and IIIS with 3. Venter brownish and variegated in colour. Approximately six pale yellowish bands on posterior margins of connexivum.

Measurements: see Table 3.2.

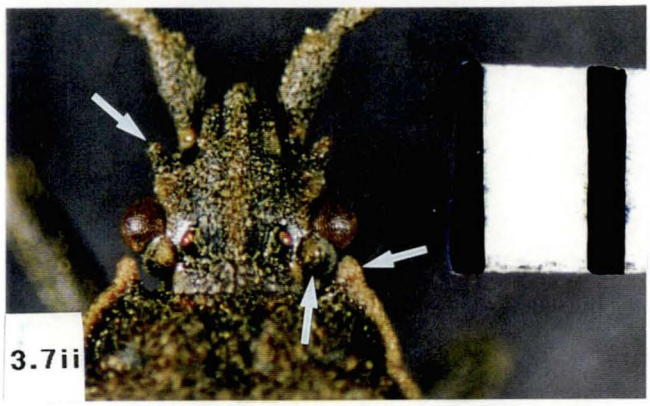
Table 3.2. Linear body measurements of type specimens of *Acantholybas* Breddin. (Measurements in millimeters.)

Specimen	Head length	Inter-ocellar space	Inter-occular space	Width across eyes	Antennal segments I-IV	Rostral segments I-IV	Pronotum length	Pronotum width	Scutellar length	Scutellar width	Total body length
A. kirkaldyi male neotype	1.72	0.62	1.09	1.76	0.80, 1.60, 1.18, 1.43	1.92, 1.96, 1.64, 2.10	2.15	3.70	1.80	1.96	10.86
A. kirkaldyi female paratype	1.72	0.64	1.11	1.84	0.76, 1.67, 1.23, 1.37	2.05, 2.05, 1.72, 2.25	2.45	3.90	2.05	2.20	11.57
A. brunneus male paralectotype	1.23	0.47	0.87	1.53	0.80, 1.47, -, -	-, -, -, -	1.80	2.50	1.31	1.23	8.40
A. brunneus female lectotype	1.34	0.53	0.96	1.63	0.89, 1.57, -, -	-, -, -, -	2.15	2.93	1.52	1.50	9.10
A. longulus male holotype	1.52	0.56	0.98	1.68	1.11, 2.00, -, -	1.68, 1.84, 1.56, 1.60	2.45	2.93	1.76	1.52	10.00

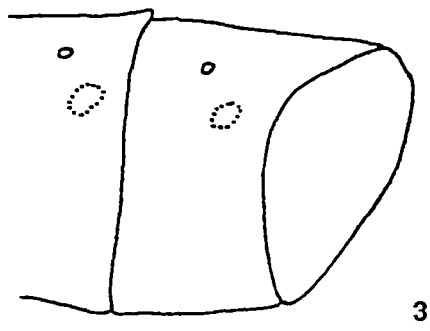
Figs 3.5i-3.5iii. Dorsal views of: **(3.5i)** *A. brunneus* (luteous bands on connexivum and spot on scutellum highlighted by arrows); **(3.5ii)** *A. kirkaldyi*; **(3.5iii)** *A. longulus* (holotype) (genital capsule slightly everted). (Scale line interval = 1 mm.)



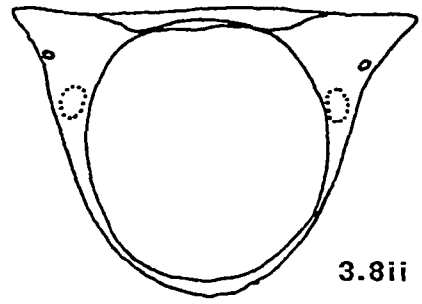
Figs 3.6i-3.6iii. Lateral views of: **(3.6i)** *A. brunneus*; **(3.6ii)** *A. kirkaldyi* (pale evaporatorium and trichobothrial pit highlighted by arrows); **(3.6iii)** *A. longulus* (holotype) (genital capsule slightly everted, highlighted by arrow). (Scale line interval = 1 mm.)



Figs 3.7i-3.7iii. Dorsal views of heads of: **(3.7i)** *A. brunneus*; **(3.7ii)** *A. kirkaldyi* (prominent antenniferous and pronotal tubercles and swelling behind eye highlighted by arrows); **(3.7iii)** *A. longulus* (holotype). (Scale line interval = 1 mm.)



3.8i



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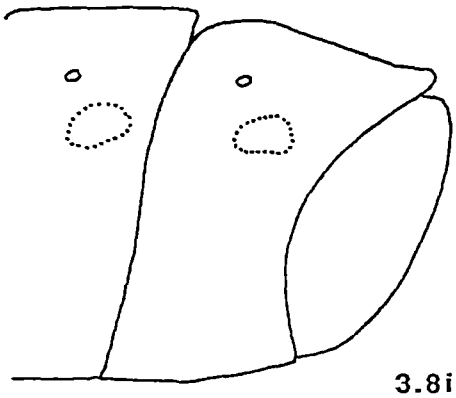
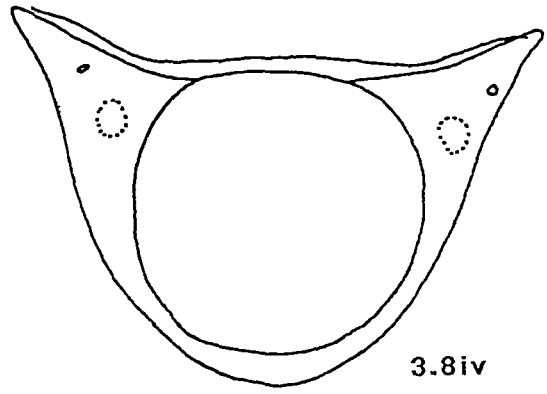
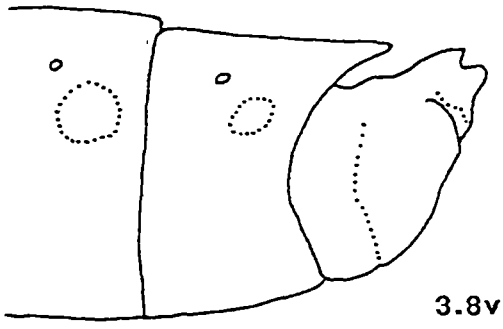


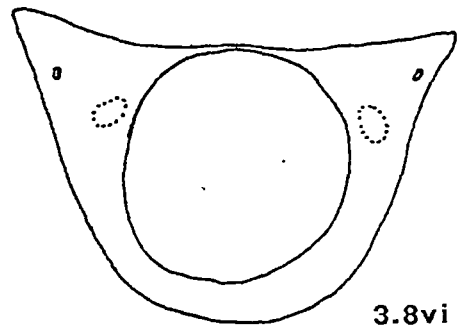
3.8iii



3.8iv

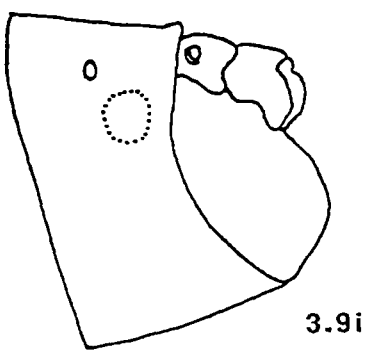


3.8v

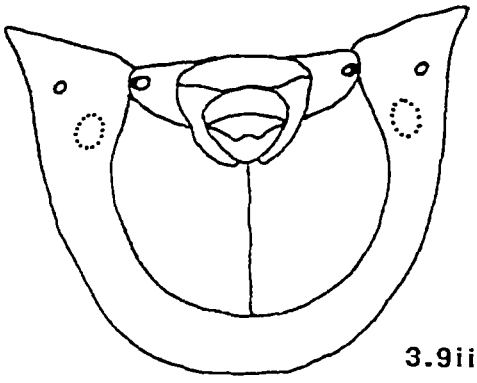


3.8vi

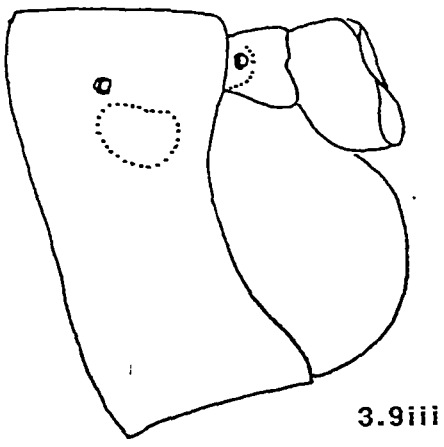
Figs 3.8i-3.8vi. Lateral and frontal views, respectively, of ♂ genital plates of: **(3.8i, 3.8ii)** *A. brunneus*; **(3.8iii, 3.8iv)** *A. kirkaldyi*; **(3.8v, 3.8vi)** *A. longulus* (holotype) (genital capsule slightly everted).



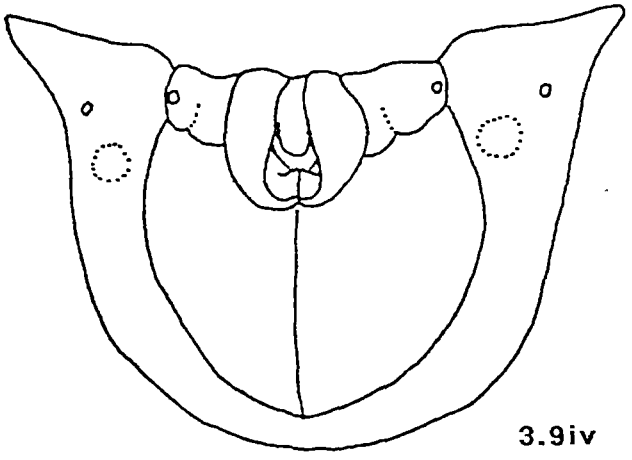
3.9i



3.9ii



3.9iii



3.9iv

Figs 3.9i-3.9iv. Lateral and frontal views, respectively, of ♀ genital plates of: (**3.9i, 3.9ii**) *A. brunneus*; (**3.9iii, 3.9iv**) *A. kirkaldyi*.

3.3iic. *Amorbus* Dallas.

Amorbus Dallas (1852) «key to the family "Mictidae" and genus description, in English»; *Amorbus* Stål (1865) «key to the subfamily "Coreida", in Latin»; *Amorbus* Mayr (1868) «German genus description»; *Amorbus* Walker (1871) «English key to the family "Mictidae", list and key to species»; *Amorbus* Stål (1873) «key to the division "Amorbaria" and description, in Latin».

Genus diagnosis

Antenniferous tubercles absent; bucculae present; anterior lateral margins of pronotum with tubercles; hind femora of males incrassate and typically armed; tibiae of males typically armed with medial spine; macropterous.

Genus re-description

Head. Labium short, reaching prothorax. Antenniferous tubercles absent; dorsal region posterior to each eye not swollen. Bucculae present. First antennal segment not distinctly swollen.

Thorax. Anterior margins of pronotum produced into tubercles. Scent gland opening of males typically swollen and evaporatorium varyingly coloured, typically concolourous with surrounding thorax in females. Hind femora sexually dimorphic. Femora of males incrassate and typically armed; tibiae typically armed with medial spine.

Abdomen. Abdomen not dorsoventrally enlarged. Trichobothria small and highly apparent, trichobothria located medially on sterna IIIS and IVS, laterally on sterna VS, VIS and VIIS. Lateral margins of connexivum marked with dorsal luteous bands in some species.

Genus notes

Typically *Amorbus* species are large, robust and brown. The sexes are dimorphic with respect to the hind femora, with those of the males being incrassate (thickened or swollen). Mitchell (1980b) found that males of *Acanthocephala femorata* (F.) (Coreidae) used their incrassate hind femora to repel rival males from their territories, thereby enhancing their mating success. Males also possess expanded or spined hind tibiae. Carver *et al.* (1991) noted that the genus *Amorbus* is represented by 15 species of highly similar appearance in Australia. The relatively large number of *Amorbus* species is taken as possible evidence that, of the Australian Coreinae, this is the only group which has undergone any degree of evolutionary radiation.

The situation with regard to the species identity of *Amorbus* in Tasmania has not been straight-forward and could still require modification. Communications with Dr G.F. Gross during early 1992 (*in lit.*) gave me to believe that *Amorbus angustior* and *A. obscuricornis* were synonyms for *A. rubiginosus*. This situation was to change in early 1993 when Dr Gross reported on the findings of Dr Ivor Lansbury (Hope Entomological Collections, Oxford University Museum). Dr Lansbury's (*in lit.*) observations led him to consider that *A. obscuricornis* was synonymous with *A. rubiginosus*, whilst *A. angustior* was considered to be a distinct species. The situation was confused still further when in mid 1993 Dr Gross wrote "...I had *angustior* and *rubiginosus* as the same species..." (*in lit.*). Given that his key to *Amorbus* cited *A. obscuricornis* and *A. affinis* as synonyms for *A. rubiginosus* it is to be assumed that "*angustior*" should have read "*obscuricornis*". Thus, since this time, I have considered *A. rubiginosus* as being recognised as a unique species, whose synonyms include *A. affinis* (Westwood).

Prior to receiving the following taxonomic key written by Dr G.F. Gross I had recognised *Amorbus* n. sp. 1 to 5 as *Amorbus* n. sp. A to E. Given that Dr Gross identified these species prior to my work I subsequently adopted his naming system. Thus, the key given below does not include the two additional species I describe in this chapter, namely *Amorbus* n. sp. 6 and 7. This key also includes a couplet identifying *Amorbus* n. sp. 2 which I do not consider to be a valid species. Having examined the types on which the description of *Amorbus* n. sp. 2 has been based, I believe these specimens are actually small *A. rubiginosus*. Additionally, although Dr Gross has accepted my proposed synonymy of *A. obscuricornis* and *A. angustior*, he has chosen to use the latter name in couplet 16. (15) based on their page priority in Westwood's original descriptions. This key also identifies *A. rhombeus* which I consider is probably conspecific with *A. rhombifer*.

"TENTATIVE KEY TO SPECIES OF *AMORBUS*

By Gordon F. Gross (24 January 1993, revised 17 October 1994) (*in lit.*)

(Mostly to males as some females are hard to separate)

1. (0) Corium and clavus bicolorous with either the whole posterior quarter paler than the anterior, or with a luteous macula or distinctly lighter coloured area near the inner angle of the corium...2.

   Corium may be laterally narrowly black anteriorly but otherwise corium and clavus the same colour all over, whether both blackish, infuscated, brownish or even yellowish and without large paler patches or maculae though if a fine granulation present the raised granules may be paler than the surface beneath them...4.

2. (1) Hind femora brown: hind tibiae brown in basal half but yellowish in apical half; posterior portion of corium yellowish, anterior three quarters of corium and all of clavus brown or yellowish grey...*robustus* Mayr, 1865.

   Hind femora and tibiae not as above; a luteous macula or pale area near inner angle of corium...3.

3. (2) Appearing brown above; on hind margin of corium on each side just exterior to inner angle a round luteous spot; hind femora yellow in their basal halves and brown in their apical halves; tibiae yellowish with a broad, medial, transverse, brown band...*biguttatus* Stål, 1873.

   Appearing black above; inner angle of corium and narrowly along hind margin dull yellowish; femora and tibiae black...n. sp. 1 [Cairns District].

4. (1) Pronotum, scutellum and laterotergites rugulose or punctate, corium and clavus punctate, corium and clavus punctate; without fine raised granules on dorsal surfaces (should be examined under several magnifications as under low magnification and in some lights the rugulosities and punctations may look like granulations); sometimes finely pilose at least on apex of head above and on basal antennal segments but both upper and lower body surfaces in which case on corium and clavus each hair arises from a punctation...5.

   Most of coriaceous parts of dorsal surface, basal antennal segments and very often femora covered with fine raised, almost pedicellate, granules, these granules may be somewhat paler than surfaces below...8.

5. (4) Lateral margins of abdomen not strongly expanded; hind tibiae of male with a prominent tooth medially which is much longer than any of the other denticles making up the serrate hind margin of the tibiae...*hirticulus* Dallas, 1852.

   Lateral margins of abdomen usually flared strongly outwards, but whether so or not hind tibiae of male with a protuberance with several large teeth, or with a medial tooth only slightly longer than the other denticles on the hind margin...6.

6. (5) Lateral margins of abdomen not strongly expanded and smaller than other species of *Amorbus*; hind femora of male with a short, low keel beneath in apical quarter only...n. sp. 2 [Yaralumla, ACT].

   Lateral margins of abdomen strongly flared outwards; of normal size for the genus; hind femora of male with a keel or row of tubercles running the whole length beneath, or obsolete only apically...7.

7. (6) Brownish; last segment of antennae relatively short; hind femora of male with one short spine apically; hind femora of male with one short spine, or without a spine, apically but with a distinct raised keel running along its internal margin then apically curving outwards and becoming obsolete well before apex of femur...*rhombeus* (Westwood, 1842). [synonym *rubicundus* Stål, 1859]

   Rather more blackish; last segment of antennae longer; hind femora of male with a line of tubercles running the whole length of the ventral surface as an obsolete keel...*rhombifer* (Westwood, 1842).

8. (4) Upper surfaces almost black; antennae entirely black...*abdominalis* Dallas, 1852. [Vic. & SA only]

Upper surfaces grey, yellowish, yellowish brown, brown, or very dark brown; at least one segment of antennae at least paler in part, or all segments brown.. 9.

9. (8) Last segment of antennae wholly pale, others dark brown or grey; hind femora of male with a small pre-terminal spines dorsally and ventrally, dorsally with a row of separated tubercles, ventrally with a low granulate keel...*atomarius* Stål, 1873.

Last segment of antennae dark, or if pale then only partly so or at least one other segment pale; if hind femora with a low, long keel and with a row of tubercles dorsally then with two apical tubercles in the form of short spines...10.

10. (9) Hind femora of male beneath with a low granulate keel anteriorly and posteriorly a row of at least three subapical spines; hind femora of female with a low serrate keel anteriorly and posteriorly a row of obsolete granules...*alternatus* Dallas, 1852. [? synonym *damelus* Distant, 1911]

Hind femora of male and female differently formed...11.

11. (10) Last segment of antennae yellowish or paler brown, other segments dark brown; hind femora of male with two conical or acutely triangular subapical and/or apical spines only...12.

Last segment of antennae either much darker though often paler at base, or last two segments of antennae pale and first two light brown; hind femora of male with one acute apical spine, or with one large, flattened, broadly triangular process at about 2/3 length to apex...13.

12. (11) Laterotergites with strongly marked pale transverse bars; occurring in highlands of southeastern Australia and southern Queensland [specs. in ANIC, NSW Dept Agric , MV and Cal. Acad]...n. sp. 3

Laterotergites uniformly coloured; occurring in southwestern Australia only.. *bispinus* (Westwood, 1842).

13. (11) Hind femora of male with a short, single, acutely triangular, subapical process; hind tibiae with only 4-6 short, obscure teeth apically of the median triangular process which has at its apex a prominent, somewhat reflexed, tooth; anterior rim of orifice of scent gland in male distinctly swollen but concolorous with orange colour of thorax beneath; females not able to be distinguished from *angustior* at this stage. [Occurs in mallee areas of northwestern Victoria and western and eastern SA]...n. sp. 4.

Hind femora of male with a broad, triangular, ventral process centred at about apical 2/3 to 3/4 of distance from base to apex of femur; hind tibiae with either more than six obvious teeth or strongly scalloped into four crenulations; anterior margin of male scent gland swollen or not, if swollen distinctly yellow and strongly contrasting with brown underside of thorax; females of *angustior* below at this stage not able to be distinguished from the preceding species. .14.

14. (13) Hind tibiae of male crenulate or scalloped into the form of four blunt teeth or lobes; rear margin of pygophore appearing vaguely three lobed in lateral view. [Known only from the unique male holotype from Melville Island, NT]...*subserratus* (Westwood, 1842).

Hind tibiae of male with more than six fairly sharp and much thinner teeth; hind margin of pygophore forming more of a smooth curve but with an apparent swelling medially...15.

15. (14) Colour above light brown to yellowish brown; lateral margins of pronotum and anterior 4/7 of margins of coria narrowly black [from arid S.A. and N.T.]...n. sp. 5.

Dark brown above; extreme lateral margins of pronotum yellow; coria concolorous for the entirety of their length [occurs in the wetter parts of eastern and southern Australia to as far west as Adeliade] ..16.

16. (15) In males anterior margin of scent gland strongly swollen and whole rim intensely yellow and strongly contrasting with brownish underside of thorax; hind femora of both males and females speckled but without a row of small, pale, slightly raised maculae dorsally [Qd, NSW, Tas., Vic., Adelaide area]...*angustior* (Westwood, 1842). [synonym *obscuricornis* Westwood, 1842].

In males anterior margin of scent gland concolorous with adjacent areas of underside of thorax and not strongly swollen; hind femora of males and females speckled and with dorsally a row or rows of glabrous, somewhat raised, pale spots. [Widely distributed] ..*rubiginosus* (Guérin-Méneville, 1838). [synonym *affinis* Westwood, 1842]."

#1 *Amorbus abdominalis* Dallas

A. abdominalis Dallas (1852) «Latin and English descriptions, respectively»; *A. abdominalis* Walker (1871) «listing only»; *A. abdominalis* Stål (1873) «listing only».

Number of specimens examined: 0.

Re-description

A specific re-description is not given as no specimens which could be identified with certainty as *A. abdominalis* were examined (see species notes).

Species notes. Four specimens (1 IV and 1 V(♂) instar nymphs, 1 adult ♂ and 1 adult ♀) from the WAM identified as *A. abdominalis* by G.F. Gross were examined. Comparison of the ♂ specimen with Dallas' (1852) description is somewhat difficult due the state of preservation of the specimen, which is covered in a fine layer of dust, is missing 2 antennal segments, the right fore, both mid and left hind legs. Although the specimen's length (20.1 mm) agrees with Dallas' description, the specimen's hind femur does not posses "a strong tooth near the apex beneath", nor could its abdomen be said to be red in colour. At most, the hind femur of the specimen appears to have only a very slight apical "mound". Whether the ♀ specimen discussed above is conspecific with this ♂ specimen is also difficult to ascertain. Although the two specimens are of approximately similar size and generally dark in colour from above, the ♀ specimen possesses small, but distinct, spines on the apices of the hind femora unlike the ♂ specimen. In addition, as the holotype description for this species is of a ♂ specimen, it may not be possible to be certain that the ♀ specimen belongs to *A. abdominalis*.

The two nymphal specimens were presumably identified based on the fact that they were collected from the same location and at the same time as was the adult ♀. As it is not possible to be certain of these specimens identities simply on the basis of identical collection records, I simply refer to them as *Amorbus* sp.

Although I disagree with some aspects of the species identifications for the two adult specimens I have not re-labelled the specimens. As these two specimens appear to constitute all the known specimens of this "species" it is not possible to confirm, or deny, that these individuals are truly *A. abdominalis* without examination of the holotype.

#2 *Amorbus alternatus* Dallas

A. alternatus Dallas (1852) «Latin and English descriptions, respectively»; *A. alternatus* Walker (1871) «listing only»; *A. planus* Walker (1871) «Latin and English descriptions, respectively»; *A. alternatus* Stål (1873) «listing and Latin description»; *A. alternatus* Distant (1900) «listing only»; *A. damelus* Distant (1911) «English description»; *A. alternatus* Blöte (1938) «listing only»; *A. alternatus* Kumar (1965) «genitalia and alimentary organs description»; *A. damelus* Gross (1969 *in lit.*) «species notes made re. type».

Number of specimens examined: 126 (Appendix 2).

Re-description

Head (Fig. 3.32i): Rostrum not reaching fore coxae. Antennal segments I and II dark, antennal segment III pale orange colour, basal ¼ of antennal segment IV concolourous with segment III, while distal ¾ of segment IV either pale yellow or concolourous with segments I and II, depending upon the preservation of the specimen.

Thorax (Fig. 3.25i): Evaporatorium concolourous with surrounding surface. Lateral margins of the pronotum with a dark border above extending down the hemelytra for less than half their length. Hind femora of ♂♂ distinctly incrassate, ♀♀ not incrassate. Hind femora of both sexes terminating before the apex of the abdomen. Numerous large, pale, slightly raised maculae present on hind femora of both sexes. Five prominent, pale yellow spines dorsally on hind femora of both sexes, these spines linearly arranged, increasing in size distally; hind femora of both sexes also with a small keel, which subsides before culminating in a single apical spine near the tibial joint. Hind tibiae of both sexes possesses a single medial spine. Hemelytra reaching apex of abdomen.

Abdomen (Fig. 3.10i): Dorsal surface typically darker than the ventral surface. Five broad, yellow bands on anterior margins of connexivum.

#3 *Amorbus angustior* (Westwood)

Physomerus angustior Westwood (1842) «Latin description»; *Amorbus angustior* Dallas (1852) «listing only»; *A. angustior* Mayr (1868) «German description»; *A. angustior* Walker (1871) «listing only»; *A. angustior* Stål (1873) «listing only»; *A. angustior* Distant (1901) «listing and English description, respectively»; *A. angustior* Lansbury (1992 *in lit.*) «species notes made re. type».

Number of specimens examined: 1 (Appendix 2).

Re-description

Head (Fig. 3.19i): Antennae of ♂ holotype incomplete. Rostrum terminating well past fore coxae.

Thorax (Figs 3.19i, 3.25ii, 3.29i): Evaporatorium yellow, distinctly swollen. Hind femora without large luteous maculae, with an internal, triangular flattened keel ¾ of the way along its length and a small spine near tibial joint. Hind tibia armed with a flattened medial keel half way along it's length, just behind this keel, tibia with a broad, diffuse pale yellow band. Posterior apex of scutellum with a pale yellow spot. Extreme lateral margins of pronotum with pale yellow edges. Hemelytra extending to apex of abdomen.
Abdomen (Figs 3.10ii, 3.19i): Dorsal surface of similar brownish, orange colour as ventral surface. Approximately 4-5 small, yellow, spots on anterior lateral margins of the connexivum.

Species notes. The type specimen of *A. angustior* is very similar to *A. obscuricornis* and given that the distribution of *A. obscuricornis* extends to the mainland (i.e. the type locality of *A. angustior*) it is possible that these "species" maybe conspecific. The possible synonymy of *A. angustior* and *A. obscuricornis* is considered thoroughly in the section on *A. obscuricornis*.

#4 *Amorbus atomarius* Stål

A. atomarius Stål (1873) «Latin description».

Number of specimens examined: 39 (Appendix 2).

Re-description

Head (Fig. 3.32ii): Antennal segment IV entirely pale yellow, all other segments dark brown or grey. Rostrum passing fore coxae.
Thorax (Figs 3.19ii, 3.25iii): Evaporatorium mostly concolourous with surrounding thorax, sometimes paler. In larger adult specimens dorsal surfaces of hind femora possess a few, slightly raised pale maculae. Hind femora of ♂♂ distinctly swollen, ♀♀ not incrassate; hind femora of both sexes possessing a small distinct keel culminating in a small apical spine above which is a line of smaller spines (about 6 are visible with the naked eye in larger specimens), which terminate near the tibial joint, dorsal to the lower "keel spine". Hind femora of both sexes not reaching apex of abdomen. Hind tibiae of ♂♂ distinctly reflexed, possessing a very prominent, flattened, medial spine; hind tibiae of ♀♀ slender, not distinctly reflexed, possessing a small medial spine. Hemelytra just reaching apex of abdomen.
Abdomen (Fig. 3.11i): Transverse, pale yellow, bars evident dorsally on the laterotergites. Ventrally, the whole body pale yellow and green, paler than the dorsal surface (light grey or brown colour).

Species notes. *A. atomarius* can be separated from *Amorbus* n. sp. 3, which is morphologically similar, by the presence of an entirely luteous fourth antennal segment and by having a concolourous evaporatorium. The evaporatorium of *Amorbus* n. sp. 3 is a reddish colour.

#5 *Amorbus biguttatus* Stål

A. biguttatus Stål (1873) «Latin description».

Number of specimens examined: 5 (Appendix 2).

Re-description

Head (Figs 3.19iii, 3.32iii): Antennal segments I-III are light brown, segment IV is ¼ light brown (proximal end) and ¾ pale yellow (distal end). Rostrum terminating between fore coxae.

Thorax (Figs 3.11ii, 3.19iii, 3.25iv): Evaporatorium concolourous with surrounding thorax. Proximal half of hind femora yellow, distal half black; hind femora of ♂♂ with a row of 8-9 small spines running dorsolaterally on the inner side; without large, raised, maculae. Hind tibiae of ♂♂ armed with a flattened, medial, spine; ♀♀ un-armed and slender; hind tibia of both sexes black near femorotibial joint and around medial spine, remainder yellow. Hemelytra with two circular, palely luteous markings at base of corium just above hemelytral membrane; just surpassing apex of abdomen; anterior of hemelytral membrane black.

Abdomen (Figs 3.11ii, 3.19iii): Margins of laterotergites forming connexivum of ♂♂ luteous and concolourous.

Species notes. *A. biguttatus*, together with *Amorbus* n. sp. 5, are mostly pale yellow coloured species and differ markedly from other *Amorbus* species which are generally brown in colour.

#6 *Amorbus bispinus* (Westwood)

Physomerus bispinus Westwood (1842) «Latin description»; *Amorbus bispinus* Stål (1873) «listing only»; *A. bispinus* Distant (1901) «listing only»; *A. bispinus* Blöte (1938) «listing only»; *A. bispinus* Lansbury (1992 *in lit.*) «species notes made re. types».

Number of specimens examined: 74 (Appendix 2).

Re-description

Head (Fig. 3.33i): Antennal segments I-III black with red joints. Antennal segment IV entirely light brown. Rostrum surpassing fore coxae.

Thorax (Figs 3.20i, 3.26i, 3.29ii): Evaporatorium red, slightly swollen, surrounding

thorax dark purple/black. Legs all distinctly darker than body. Hind femora of ♂♂ with two flattened spines distally, the proximal spine larger than the distal; hind femora of ♀♀ with one distal spine; hind femora of both sexes without obvious maculae. Hind tibiae of ♂♂ slightly recurved outward with a slightly flattened spine ¾ way along their length; hind tibiae of ♀♀ un-armed and slender. Hemelytra not surpassing apex of abdomen; hemelytral membrane black and strongly contrasting with light brown of coriaceous portion, darker than clavus, corium and cuneus.

Abdomen (Figs 3.12i, 3.20i): Ventral surface usually light yellow and noticeably contrasting with thorax.

#7 *Amorbus hirticulus* Dallas

A. hirticulus Dallas (1852) «Latin and English descriptions, respectively»; *A. hirticulus* Walker (1871) «listing only»; *A. hirticulus* Stål (1873) «listing only»; *A. hirticulus* Blöte (1938) «listing only»; *A. hirticulus* Gross (1969 *in lit.*) «species notes made re. type».

Number of specimens examined: 0.

Re-description

A specific re-description of this species is not given as no specimens were examined.

Species notes. Of all the *Amorbus* specimens examined none could be definitely assigned to this species. The original description and associated notes are given in Appendix 1. According to the notes on the type specimen made by Dr G. Gross this species is very similar in general appearance to *A. alternatus*.

#8 *Amorbus obscuricornis* (Westwood)

Physomerus obscuricornis Westwood (1842) «Latin description»; *Amorbus obscuricornis* Dallas (1852) «listing only»; *A. obscuricornis* Mayr (1868) «German description»; *A. obscuricornis* Walker (1871) «listing only»; *A. obscuricornis* Stål (1873) «listing and Latin description»; *A. obscuricornis* Distant (1901) «listing only»; *A. obscuricornis* Blöte (1938) «listing only»; *A. obscuricornis* Lansbury (1992 *in lit.*) «species notes made re. type».

Number of specimens examined: 416 (Appendix 2).

Re-description

Head (Figs 3.33ii, 3.37i-3.37v): Proximally antennal segments III and IV light in colour, remainder darker. Rostrum surpassing fore coxae.

Thorax (Figs 3.20ii, 3.26ii, 3.37vi-3.37viii): Evaporatorium of ♂♂ bright yellow and distinctly swollen; those of ♀♀ not as swollen and mostly concolourous with surrounding

thorax. Posterior apex of scutellum with pale yellow spot. Extreme lateral margins of pronotum yellowish. Hind femora of ♂♂ and ♀♀ without obvious maculae. Hind femora of ♂♂ armed similarly to that of *A. angustior*; hind femora of ♀♀ with a single spine distally. Hind tibiae of ♂♂ armed with a slightly flattened medial spine, region beneath this spine pale yellow; hind tibiae of ♀♀ un-armed and slender. Hemelytra touching or just surpassing apex of abdomen; clavus, corium and cuneus concolourous.

Abdomen (Figs 3.12ii, 3.20ii, 3.38i-3.38ii(♂), 3.38iii-3.38iv(♀), 3.39iv-3.39vi): Approximately five small, palely luteous spots at anterior margins of laterotergites of connexivum.

Species notes. Using measurements taken for the morphometric analysis the size of the various features examined is summarised in Table 3.3. Also presented in this table are the results obtained from measurements of fifth instar *A. obscuricornis* nymphs.

Table 3.3. Summary of morphological features of *Amorbus obscuricornis* fifth instar nymphs and adults (measurements in mm). Ranges given in parentheses.

Feature	V instar ♂♂ mean ± se n = 10	V instar ♀♀ mean ± se n = 8	Adult ♂♂ mean ± se n = 27	Adult ♀♀ mean ± se n = 26
apical antennal length	2.42 ± 0.04 (2.30-2.65)	2.26 ± 0.03 (2.10-2.40)	2.39 ± 0.03 (1.95-2.65)	2.21 ± 0.02 (2.00-2.45)
head width	1.96 ± 0.06 (1.85-2.05)	1.98 ± 0.05 (1.95-2.10)	2.05 ± 0.02 (1.85-2.20)	2.03 ± 0.01 (1.90-2.15)
pronotum width	4.19 ± 0.04 (4.00-4.40)	4.23 ± 0.07 (3.90-4.60)	5.82 ± 0.14 (4.25-7.10)	5.78 ± 0.11 (4.80-6.90)
mid femur length	4.73 ± 0.05 (4.50-4.95)	4.62 ± 0.06 (4.40-5.00)	4.82 ± 0.08 (4.00-5.30)	4.60 ± 0.05 (4.25-4.95)
hind femur length	6.13 ± 0.08 (5.90-6.60)	6.04 ± 0.09 (5.70-6.50)	6.72 ± 0.17 (4.90-7.80)	6.05 ± 0.08 (5.30-6.90)

During the 3½ years that I have been collecting *A. obscuricornis* adults in Tasmania I have observed a number of body colourations ranging from light reddish/brown to almost black. In glasshouse experiments individuals from either end of this colour spectrum were observed to mate readily. Anecdotally, some parent adults appeared more reddish/brown in colour than their glasshouse reared progeny. An investigation into this phenomenon may elucidate the important colour determining factors. Predictably, specimens which have been pinned for sometime and/or exposed to sunlight fade and appear pale reddish/brown.

SEM studies of antennal segment IV of "*A. obscuricornis* Tasmania" adults (Figs 3.37i-3.37iv) revealed a change in the composition of bristle types from the basal quarter to the apical ¾ of the antenna. At this point a transition from only moderate sized bristles on small raised maculae to similar bristles surrounded by much finer "hair-like" bristles occurs. This transition zone appears as a change in colour from yellow to brown/black. At the very end of antennal segment IV is a small denudate, "nipple-like", protrusion. At the apex of the rostrum a number of moderate sized bristles are evident (Fig. 3.37v). The maculae of the hind femora (Figs 3.37vii, 3.37viii) are only slightly raised and each bears a small bristle. All of these features were shared with specimens of "*A. obscuricornis* mainland". The parameres of Tasmanian and mainland specimens of *A. obscuricornis* were not obviously different (Figs 3.39i-3.39vi). The differences observed are likely attributable to within species variation.

Much effort has been directed towards determining whether significant differences occur between populations of *A. obscuricornis* from Tasmania and the mainland. The primary aim of this work was to ascertain whether *A. angustior* (mainland type locality) and *A. obscuricornis* (type locality Tasmania) might be synonyms, given that Westwood (1842) (Appendix 1) wrote of *A. obscuricornis*: "very much akin to the previous ones" (namely *A. affinis*, *A. angustior* and *A. subserratus*) "and perhaps a geographical variety...". Having viewed these types, as well as additional specimens, I concur with the synonymy of *A. affinis* and *A. rubiginosus* and consider *A. subserratus* to be a unique species. Thus, all that is necessary is the differentiation of *A. angustior* and *A. obscuricornis*. All of the evidence gathered (inc. original descriptions and notes from colleagues, light and SEM microscopy, paramere studies) gives me to consider it likely that "*A. obscuricornis* Tasmania" is conspecific with "*A. obscuricornis* mainland". Thus, I consider *A. angustior* to be conspecific with *A. obscuricornis* and suggest that the former should be recognised as a synonym of *A. obscuricornis*.

#9 *Amorbus rhombeus* (Westwood)

Physomerus rhombeus Westwood (1842) «Latin description»; *Amorbus rhombeus* Dallas (1852) «listing only»; *A. rhombeus* Walker (1871) «listing only»; *A. rhombeus* Stål (1873) «listing only»; *A. rhombeus* Distant (1901) «listing and English description, respectively»; *A. rhombeus* Lansbury (1992 *in lit.*) «species notes made re. type».

Number of specimens examined: 1 (Appendix 2).

Re-description

Head: Antennae of ♂ holotype incomplete. Rostrum level with posterior margin of fore

coxae.

Thorax (Figs 3.20iii, 3.26iii, 3.29iii): Evaporatorium concolourous with surrounding thorax, slightly swollen. Lateral margins of pronotum with luteous edges. Hemelytra with concolourous clavus, corium and cuneus, touching apex of abdomen. Hind femur with a low dorsolateral keel and without obvious maculae. Hind tibia with a slightly flattened medial spine. Ventral surface yellowish, dorsal surface brown.

Abdomen (Figs 3.13i, 3.20iii): Abdomen rhomboid in appearance, colouration similar to thorax.

Species notes. *A. rhombeus* and *A. rhombifer* appear very similar when viewed dorsally and ventrally, so much so that Distant (1901) considered them "doubtfully distinct". Gross (1994 *in lit.*) considers these species to be distinct. Although I consider these "species" very similar (possibly even conspecific), until more specimens can be collected from both the Australian mainland and Melville Island (the type locality of *A. rhombeus*) it does not seem feasible to comment on this possibility further. In the following chapter, however, I treat this species as conspecific with *A. rhombifer*.

#10 *Amorbus rhombifer* (Westwood)

Physomerus rhombifer Westwood (1842) «Latin description»; *Amorbus rhombifer* Dallas (1852) «listing only»; *A. rubicundus* Stål (1859) «Latin description»; *A. rubicundus* Mayr (1868) «German description»; *A. rhombifer* Walker (1871) «listing only»; *A. rubicundus* Walker (1871) «listing only»; *A. rhombifer* Stål (1873) «listing only»; *A. rubicundus* Stål (1873) «listing and Latin description»; *A. rhombifer* Distant (1901) «listing only»; *A. rhombifer* Blöte (1938) «listing only»; *A. rubicundus* Blöte (1938) «listing only»; *A. rhombifer* Kumar (1965) «genitalia and alimentary organs description»; *A. rhombifer* Lansbury (1992 *in lit.*) «species notes made re. type».

Number of specimens examined: 115 (Appendix 2).

Re-description

Head (Figs 3.21i, 3.33iii): Antennal segment I light orange, segments II, III and proximal ¼ of IV pale yellow. Distal ¾ of antennal segment IV dark. Rostrum surpassing fore coxae.

Thorax (Figs 3.21i, 3.26iv): Evaporatorium concolourous with surrounding thorax, not distinctly swollen. ♂♂ hind femora incrassate, possessing a low dorsolateral keel on the side nearest the body, two very small spines distally; ♀♀ hind femora not incrassate, with a single distal spine; hind femora of both sexes without obvious maculae. Hind tibia of ♂♂ with a sharp, distal, spine ¾ of way down their length; hind tibia of ♀♀ slender

and un-armed; hind tibiae of both sexes usually paler than hind femora. Hemelytra touching, or nearly touching, distal apex of abdomen.

Abdomen (Fig. 3.13ii): Very prominent due to the highly flanged appearance of laterotergites; ♀♀ distinctly more rhomboid in appearance than ♂♂. Distal apex of ♂ abdomens rounded, not forming a distinct point as in ♀♀.

Species notes. Generally, *A. rhombifer* would appear to be a larger species than *A. rhombeus*, however, size is not a particularly reliable taxonomic feature as it is subject to phenotypic variation. Couplet 7.(6) of the key to *Amorbus* species (G. Gross 1994 *in lit.*) cites *A. rubicundus* Stål as a synonym for *A. rhombeus*. However, one of the labels on the ♀ allotype reads: "Amorbus rubicundus Stål G.F. Gross, det. 1974 unpubl. synonym of Amorbus rhombifer (Westw.)". Having examined this specimen I can find no significant difference between it and specimens identified as *A. rhombifer*. Thus, I consider *A. rubicundus* to be a synonym of *A. rhombifer*.

#11 *Amorbus robustus* Mayr

A. robustus Mayr (1865) «Latin description»; *A. robustus* Mayr (1868) «Latin and German descriptions, respectively»; *A. robustus* Walker (1871) «listing only»; *A. robustus* Stål (1873) «listing and Latin description»; *A. robustus* Blöte (1938) «listing only»; *A. robustus* Schaefer (1965) «conjunctival description».

Number of specimens examined: 213 (Appendix 2).

Re-description

Head (Fig. 3.34i): Antennal segments I-III pale orange. Proximal ¼ of antennal segment IV pale orange, distal ¾ greyish/black. Rostrum surpassing fore coxae.

Thorax (Figs 3.21ii, 3.27i, 3.29iv): Evaporatorium of both sexes slightly swollen and yellow, not concolourous with surrounding thorax. Extreme lateral margins of pronotum with yellow edges, posterior corners of pronotum produced into sharp tubercles. Posterior apex of scutellum with a very small yellow spot. Hind femora of ♂♂ incrassate, those of ♀♀ less so; hind femora of both sexes reddish, with large, luteous, slightly raised maculae, usually formed into 3 distinct rows, on the near side with a row of 3 small, dorsolateral, spines which are luteous in colour and increase in size distally. Beneath these spines ♂♂ with a low keel culminating in a flattened spine distally; ♀♀ lacking keel but have two flattened spines, the proximal one of which is larger. Hind tibiae of both sexes ⅔ reddish and distally ⅓ luteous. Hind tibia of ♂♂ with a sharp medial spine which culminates a prominent keel, with prominent serrations distally; ♀♀ similar but features less pronounced. Hemelytra with two luteous regions at base of

corium, but not extending to end of cuneus; hemelytral membrane concolourous; hemelytra of both sexes either just, or not quite reaching apex of abdomen.

Abdomen (Fig. 3.14i): Anterior margins of laterotergites of connexivum with 5 small luteous spots. Two prominent swellings apparent laterally at margins of abdominal sternites IIIS/IVS and IVS/VS in ♂♂.

Species notes. From above the body appears brown in colour whilst ventrally it is reddish coloured. Generally, *A. robustus* can be readily separated from other *Amorbus* species as it is the largest member of the genus, however, small specimens are not uncommon. The swellings of the abdominal sternites are not unlike those found in *Mictis profana* (F.) (Coreidae). Flanagan (1994) referred to these features as "pheromone glands".

#12 *Amorbus rubiginosus* (Guérin-Méneville)

Coreus rubiginosus Guérin-Méneville (1830) «Latin and French descriptions, respectively»; *Physomerus affinis* Westwood (1842) «Latin description»; *Amorbus rubiginosus* Dallas (1852) «listing only»; *A. rubiginosus* Mayr (1868) «German description»; *A. rubiginosus* Walker (1871) «listing only»; *A. rubiginosus* Stål (1873) «listing only»; *A. rubiginosus* Distant (1901) «listing only»; *A. rubiginosus* Blöte (1938) «listing only»; *A. rubiginosus* Kumar (1965) «genitalia and alimentary organs description»; *A. affinis* Lansbury (1992 *in lit.*) «species notes made re. type».

Number of specimens examined: 336 (Appendix 2).

Re-description

Head (Figs 3.22i, 3.34ii): Antennal segment I greyish/black, antennal segments II-III orange, except for proximal ¼ of segment II which is darker; proximal ¼ of antennal segment IV orange, distal ¾ blackish. Rostrum just surpassing fore coxae.

Thorax (Figs 3.22i, 3.27ii): Evaporatorium concolourous with surrounding thorax and not greatly swollen, but occasionally appearing paler than surrounding area. Lateral margins of pronotum with luteous edges. ♂♂ with incrassate hind femora, ♀♀ with slender femora; hind femora of both sexes with 3 dorsolateral rows of large, luteous, slightly raised maculae on the outer surface; hind femora of ♂♂ with a triangular, flattened keel on inner surface, with a small distal spine near femorotibial joint; ♀♀ with a single distal spine. Hind tibiae of ♂♂ armed with a medial, flattened, spine, tibial serrations conspicuous; ♀♀ with slender, un-armed, hind tibiae which are pale orange and not concolourous with femora. Hemelytra of both sexes either just, or not quite reaching apex of abdomen, mostly concolourous.

Abdomen (Fig. 3.14ii): Anterior lateral margins of connexivum with small luteous spots. Abdominal laterotergites of ♂♂ are typically not as laterally expanded as those of ♀♀.

Species notes. Dorsally this species usually appears a brownish/grey colour whilst ventrally it appears a reddish colour, occasionally some ♀♀ appear cream coloured. SEM studies revealed that the luteous maculae of *A. rubiginosus*, which can be seen with the naked eye, are in the vicinity of 90 to 120 μm long (excluding apical bristle). As mentioned previously, Semmens *et al.* (1992) listed three species of *Amorbus* as inhabiting Tasmania. No *A. rubiginosus* examined by me came from Tasmania and the inclusion of this species in a Tasmanian faunal list is incorrect.

#13 *Amorbus subserratus* (Westwood)

Physomerus subserratus Westwood (1842) «Latin description»; *Amorbus subserratus* Stål (1873) «listing only»; *A. subserratus* Distant (1901) «listing and English description, respectively»; *A. subserratus* Lansbury (1992 *in lit.*) «species notes made re. type».

Number of specimens examined: 1 (Appendix 2).

Re-description

Head (Figs 3.22ii, 3.34iii): Antennal segment I greyish/black, antennal segments II-III orange/brown, except for proximal ¼ of segment II which is darker; proximal ¼ of antennal segment IV orange/brown, distal ¾ blackish. Rostrum just surpassing fore coxae.

Thorax (Figs 3.22ii, 3.27iii, 3.30ii): Evaporatorium slightly elevated and paler than surrounding thorax. Pronotum with extreme lateral margins yellow. Hind femur of holotype with 3 rows of faintly luteous, slightly raised, maculae. Hind tibia with a medial spine atop a raised keel; tibial serrations fewer in number than *A. rubiginosus* and larger in size. Hemelytra concolourous and surpassing apex of abdomen.

Abdomen (Figs 3.15i, 3.22ii): Anterior lateral margins of connexivum with 5 dully luteous spots.

Species notes. This species bears many similarities with *A. rubiginosus*, differing in colouration of maculae of hind femora, number of tibial serrations and overall body size (the holotype of *A. subserratus* is smaller than most specimens of *A. rubiginosus* I have seen). The latter characterisitic is variable and of limited taxonomic significance.

14 *Amorbus* n. sp. 1

Number of specimens examined: 3 (Appendix 2).

Description

Head (Fig. 3.35i): Antennal segments I-III of ♂ black with luteous joints. Proximal ⅓ of antennal segment IV black, remaining ⅔ yellow. All antennal segments and joints of ♀ black. Rostrum just supassing fore coxae in ♂, rostrum longer in ♀.

Thorax (Figs 3.22iii, 3.27iv, 3.30iii): Evaporatorium black, concolourous with surrounding thorax, only slightly swollen. Pronotum and scutellum of both sexes blackish, but with a small pale area anteriorly in ♀. Hind femora and tibiae of both sexes black and lacking obvious maculae. Hind femur of ♂ incrassate with a low keel terminating in a small distal spine; hind femur of ♀ slender, terminating with a small distal spine. Hind tibiae of both sexes slender, ♂ with small medial spine and low serrations. Hemelytra touching apex of abdomen in ♂, not quite touching in ♀; hemelytra of ♂ with luteous margin above membraneous portion, posterior to the clavus, corium and cuneus, concolourous in ♀.

Abdomen (Figs 3.15ii, 3.22iii): Anterior lateral margins of connexivum with 5 small, luteous, spots. Ventrally the ♂ laterotergites luteous with a brownish border, those of ♀ entirely reddish/brown.

Species notes. Viewed dorsally, the body shape of this *Amorbus* species bears a resemblance to *A. rhombifer*.

15 *Amorbus* n. sp. 2

Number of specimens examined: 2 (Appendix 2).

Description

Head (Figs 3.23i, 3.35ii): Antennal segment I greyish/black, antennal segments II-III orange, except for proximal ¼ of segment II which is darker; proximal ¼ of antennal segment IV orange, distal ¾ blackish. Rostrum surpassing fore coxae.

Thorax (Figs 3.16i, 3.23i, 3.28i, 3.30iv): Evaporatorium of ♂ paler than surrounding thorax, not greatly swollen; concolourous with surrounding thorax in ♀. Hind femora and tibiae of both sexes similar to *A. rubiginosus* but maculae and triangular, flattened, keel of ♂ less prominent. Hemelytra of both sexes concolourous, touching apex of abdomen in ♂, terminating prior to apex of abdomen in ♀.

Abdomen (Figs 3.16i, 3.23i): Small luteous spots on anterior lateral margins of laterotergites of connexivum.

Species notes. Only two specimens of this species, as identified by G.F. Gross, are known. I believe, however, that this species is conspecific with *A. rubiginosus*. The

markedly smaller size of these two specimens may be due to their having a poor level of nutrition during nymphal development. Unusually small specimens of *A. obscuricornis* have been reared under glasshouse conditions by myself when nymphs have few vigorous shoots on which to feed. I have relabelled these specimens as being *A. rubiginosus*.

16 *Amorbus* n. sp. 3

Number of specimens examined: 37 (Appendix 2).

Description

Head (Figs 3.23ii, 3.35iii): Antennal segments I-III all dark, segment IV proximally brown, distal ¾ pale yellow. Rostrum surpassing fore coxae.

Thorax (Figs 3.23ii, 3.28ii, 3.31i): Evaporatorium distinctly reddish, not concolourous with surrounding thorax. Hind femora of both sexes without obvious maculae; hind femora of ♂♂ reaching apex of abdomen, not strongly swollen, lacking distinct keels, armed with two, somewhat flattened, spines apically; hind femora of ♀♀ not incrassate, armed with one flattened spine apically. ♂ hind tibia somewhat reflexed, with a medial flattened spine; ♀ hind tibia lacking a medial spine but with a slight keel. Hemelytra typically not passing apex of abdomen.

Abdomen (Fig. 3.16ii): Distinct luteous bands apparent dorsally on laterotergites of connexivum.

Species notes. This species bears a superficial resemblance to *A. alternatus* and close resemblance to *A. atomarius*, especially when viewed dorsally. Many specimens have thus been inappropriately identified as one or other of these species, but can be readily separated from them by differences in the hind femora and colouration of the evaporatorium.

17 *Amorbus* n. sp. 4

Number of specimens examined: 7 (Appendix 2).

Description

Head (Figs 3.23iii, 3.35iv): Antennal segments I-II greyish/brown, III mottled brownish/orange, segment IV proximally brownish/orange and distally ¾ yellow. Rostrum long, reaching mesothorax.

Thorax (Figs 3.23iii, 3.28iii, 3.31ii): Anterior margin of evaporatorium slightly swollen, concolourous with surrounding thorax. Extreme lateral margins of pronotum yellow. Hind femora of both sexes without obvious maculae. Hind femora of ♂♂ incrassate, with a single, triangular, flattened keel produced into a distinct point near femorotibial joint;

♀♀ slender, with similar keel and mottled colouration. Hind tibiae of both sexes mottled luteous/brown; ♂♂ with small serrations and a medial spine which terminates a slight keel; ♀♀ with very minute serrations along distal ½ to ⅔ of its length. Hemelytra of ♂♂ touching apex of abdomen, not reaching in ♀♀. Clavus, corium and cuneus concolourous.

Abdomen (Figs 3.17i, 3.23iii): ♀ abdomen appearing rhomboid. Anterior lateral margins of connexivum with 5 luteous spots.

Species notes. Viewed dorsally this species appears an orange/brown colour whilst the ventral surface is a distinct yellow colour. The long rostrum is an obvious character separating it from most *Amorbus* species.

18 *Amorbus* n. sp. 5

Number of specimens examined: 4 (Appendix 2).

Description

Head (Figs 3.17ii, 3.36i): Antennal segments I-II pale brown, segment III proximally ¾ luteous and distally ¼ pale brown, segment IV entirely luteous. Rostrum not reaching fore coxae.

Thorax (Fig. 3.17ii): Evaporatorium of both sexes concolourous with the surrounding thorax. Dorsally, anterior lateral margins of pronotum black. Hind femora of ♂♂ incrassate, with a low, elongated keel possessesing a row of small serrations which culminate distally in a small spine; hind femora of ♀♀ not incrassate, lack a keel and possess only a minute distal spine. Dorsally, the ♂ hind tibiae brown, reflexed, with a prominent, flattened, spine medially; ♀♀ slender, brown, with a row of minute serrations for approximately ⅔ their length. Proximally, margins of coria black for approximately half their length; coriaceous portion of hemelytra, other than margins, uniformly luteous; membraneous portion of hemelytra hyaline. Hemelytra reaching or just surpassing apex of abdomen.

Abdomen (Fig. 3.17ii): Lateral margins of connexivum without distinct luteous bands.

Species notes. This is one of only two species in the genus that is not a brown, dark brown or a reddish/brown colour. In similarity with *A. biguttatus*, this species is mostly luteous in colour.

19 *Amorbus* n. sp. 6

Number of specimens examined: 23 (Appendix 2).

Description

Head (Figs 3.18i, 3.24i, 3.36ii): Antennal segment I brown/orange, segments II-III distinctly orange, segment IV proximally ⅓ orange, apically ⅔ brown/orange. Rostrum reaching mesothorax.

Thorax (Figs 3.18i, 3.24i, 3.28iv, 3.31iii): Evaporatorium of both sexes yellow, as swollen in ♀♀ as ♂♂; thorax immediately surrounding evaporatorium darker brown than that of remainder of thorax. ♂♂ with dark brown, incrassate, hind femora, no obvious maculae, with a low, triangular, keel distally. Hind tibiae of ♂♂ with a medial, flattened, keel posterior to which are approximately 9 prominent serrations. ♀ hind femora slender, dark brown, with pronounced acute, posterior, triangular keel which is orange. Hemelytra just reaching apex of abdomen.

Abdomen (Figs 3.18i, 3.24i): Dorsally, tergites IVS, VS and VIS near the margins of hemelytra are a rose colour, more apparent in ♂♂ than ♀♀; a faintly luteous lateral margin evident on tergite VIIS of ♂♂. Ventral abdominal surface concolourous.

Species notes. Bears a very close resemblance to *A. obscuricornis*, however, the two species differ with respect to colouration and degree of scent gland development between the sexes. I propose that it should be named in recognition of the rose coloured abdomen.

20 *Amorbus* n. sp. 7

Number of specimens examined: 2 (Appendix 2).

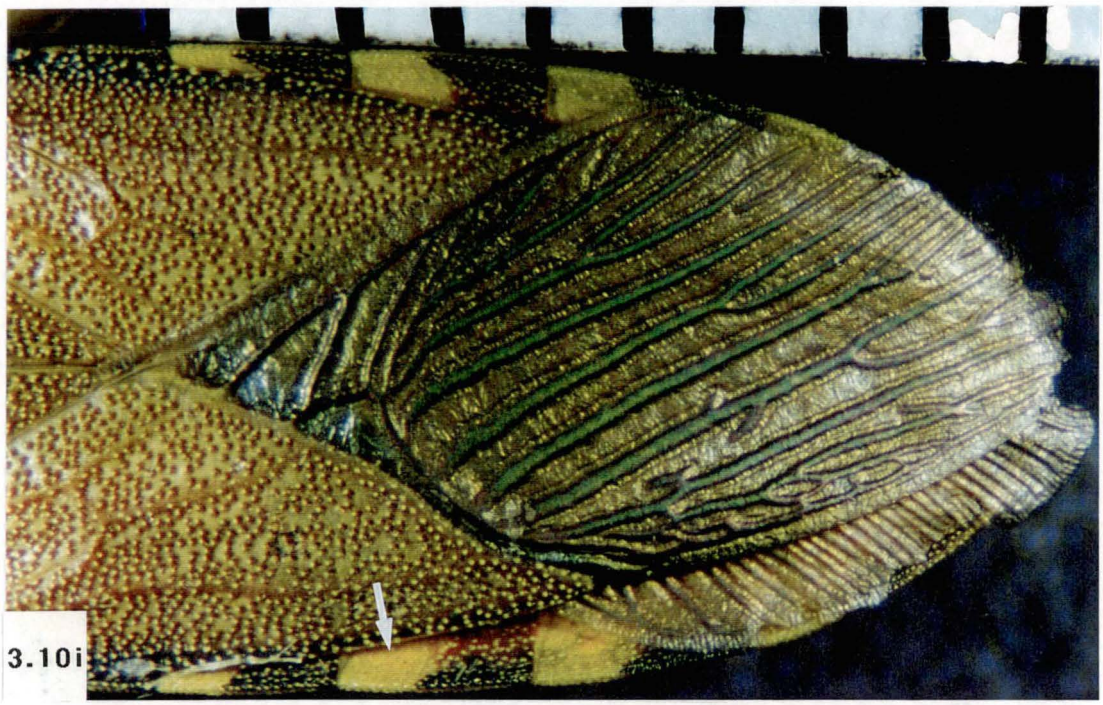
Description

Head (Figs 3.24ii, 3.36iii) ♀♀: Antennal segments I-III and proximal ¼ of IV entirely orange/brown, distal ¾ antennal segment IV black. Rostrum reaching mesothorax.

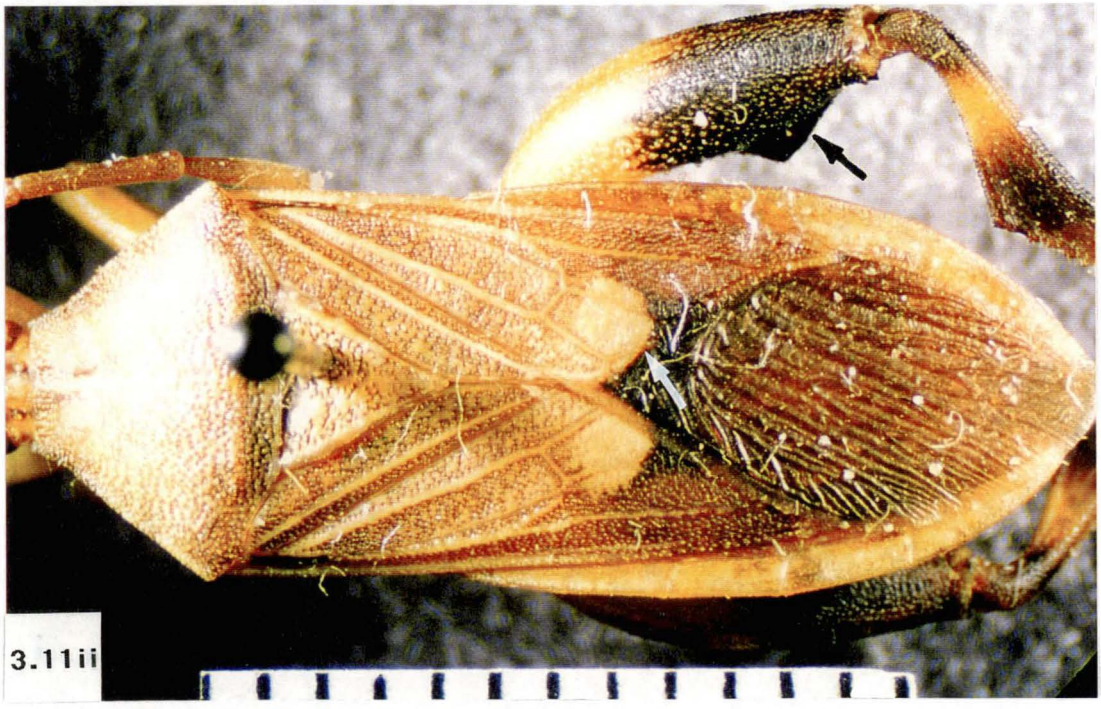
Thorax (Figs 3.24ii, 3.28v) ♀♀: Evaporatorium with a somewhat elevated anterior rim, concolourous with surrounding thorax. Lateral margins of pronotum luteous; anteriorly, pronotum with two black bands extending posteriorly for approximately ⅔ pronotum length. Dorsally, the pro-, meso- and metafemora are dark reddish/brown, without obvious maculae. Tibiae typically yellow to orange, slender and un-armed. Hemelytra not surpassing apex of abdomen, lateral margins with distinct black markings anteriorly extending down to the corium until reaching the first abdominal tergum, exterior to these black markings the corium has a luteous margin.

Abdomen (Figs 3.18ii, 3.24ii) ♀♀: Abdomen rhomboid, without luteous bands.

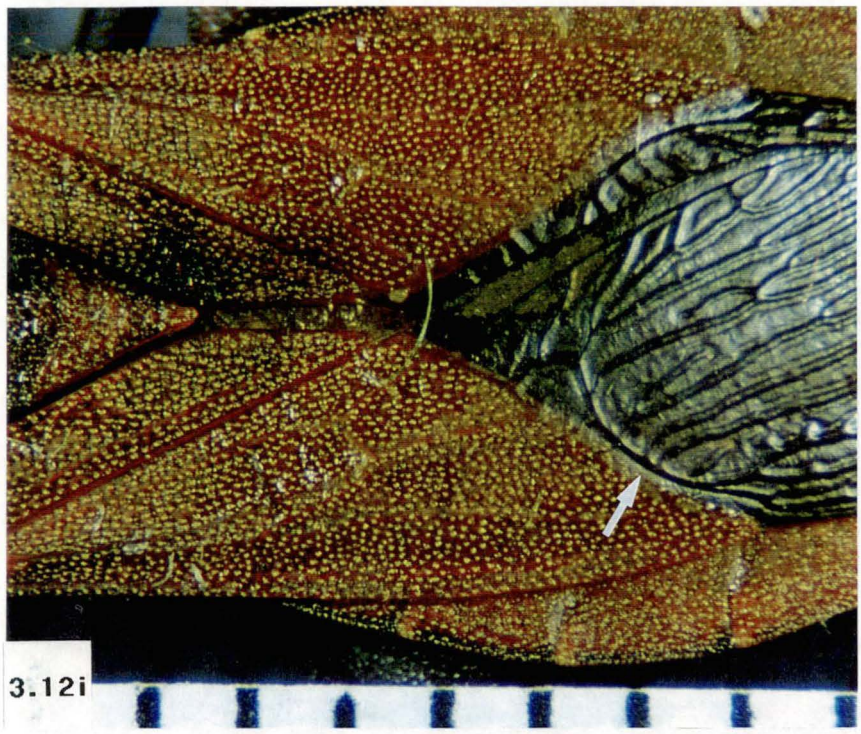
Species notes. Only two ♀ specimens are represented in the Australian collections examined, both from islands in the Torres Strait. Resembles *A. rhombifer* ♀♀.

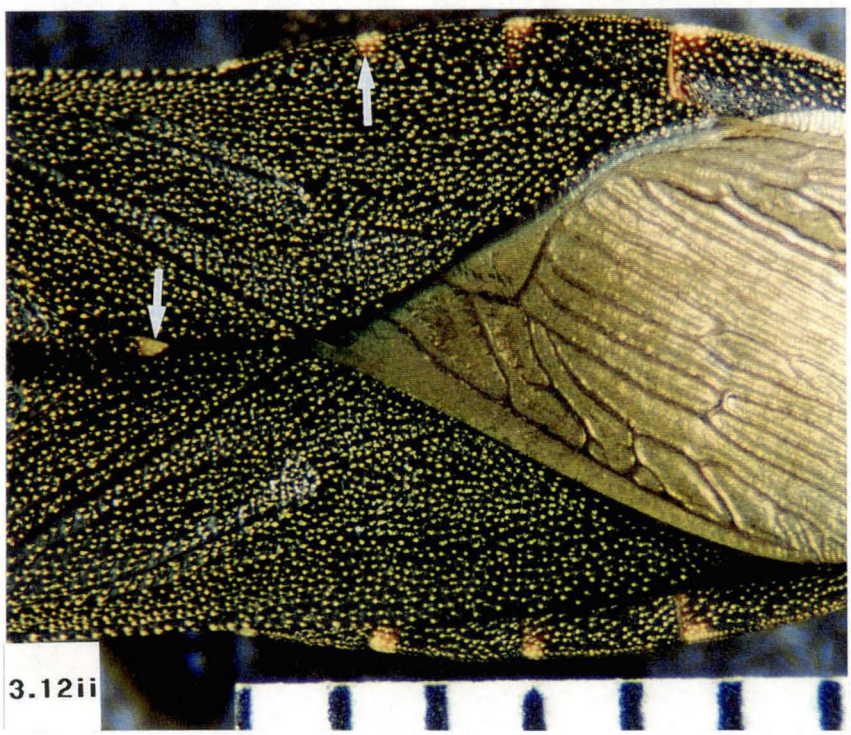


Figs 3.10i, 3.10ii. Dorsal views of: **(3.10i)** *A. alternatus*, abdomen (luteous bands on connexivum highlighted by arrow); **(3.10ii)** *A. angustior*, abdomen (holotype) (luteous spot on scutellum highlighted by arrow). (Scale line interval = 1 mm.)

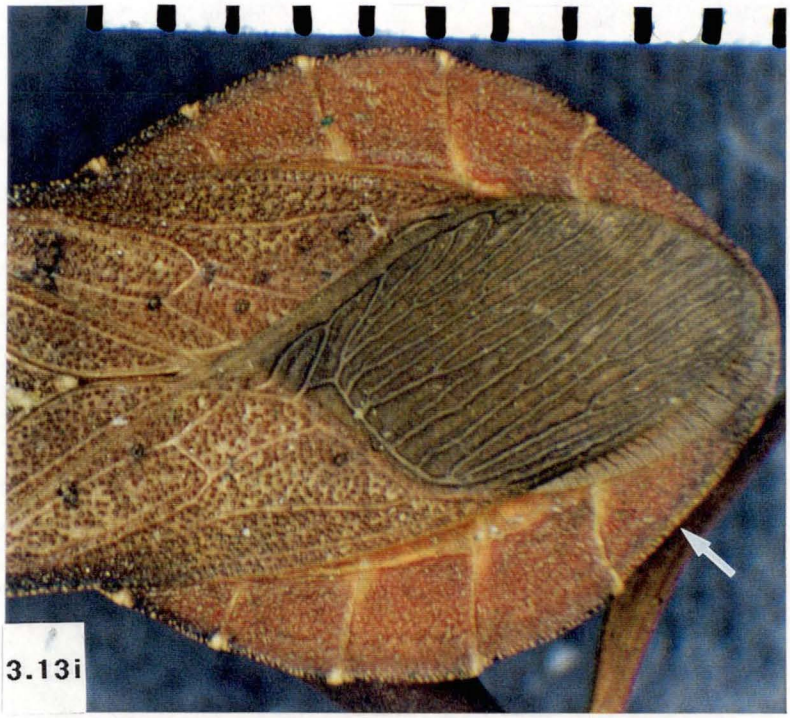


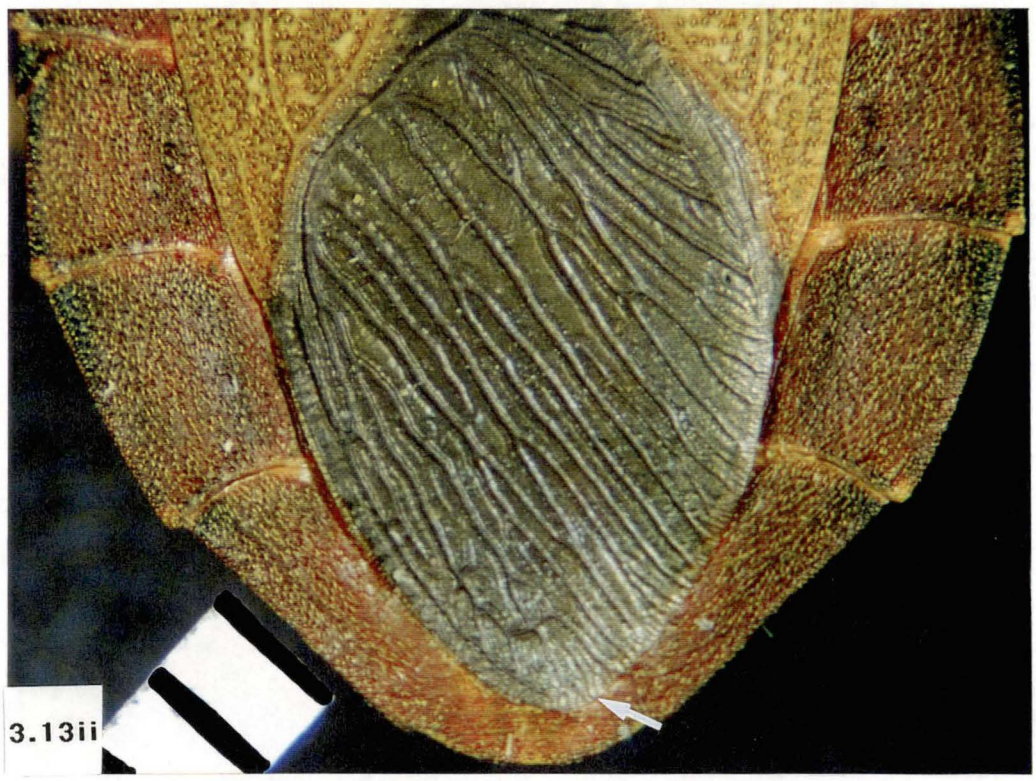
Figs 3.11i, 3.11ii. Dorsal views of: **(3.11i)** *A. atomarius*, abdomen (luteous bands on connexivum highlighted by arrow); **(3.11ii)** *A. biguttatus*, body (luteous region on hemelytron and dark distal portion of hind femur highlighted by arrows). (Scale line interval = 1 mm.)



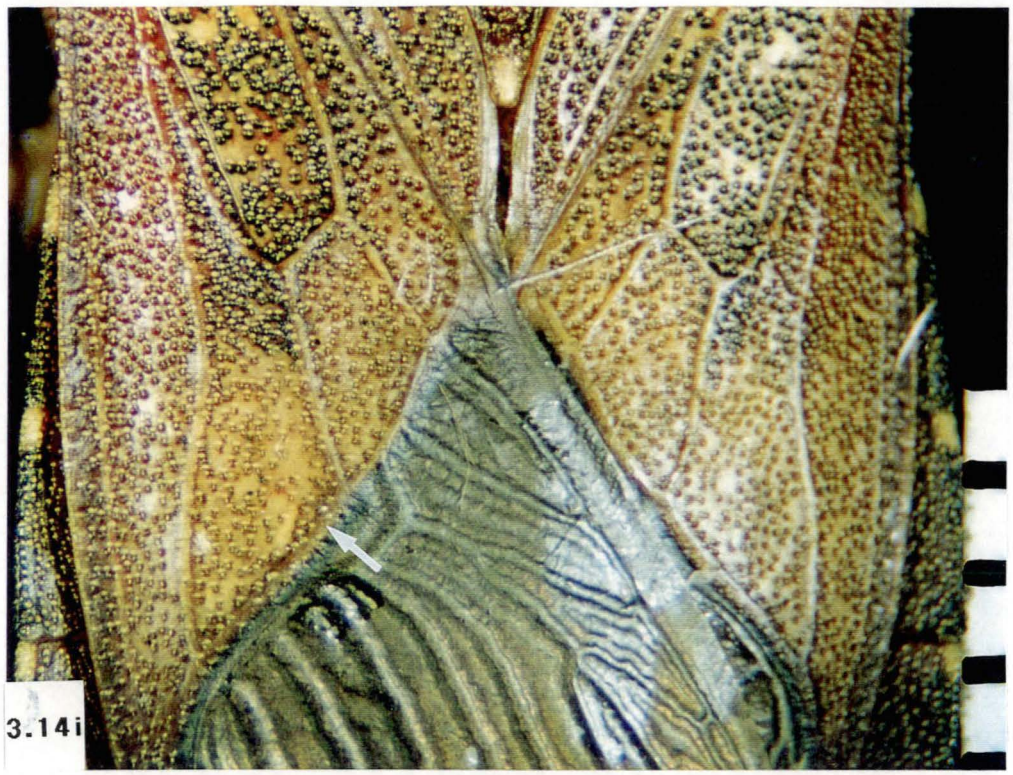


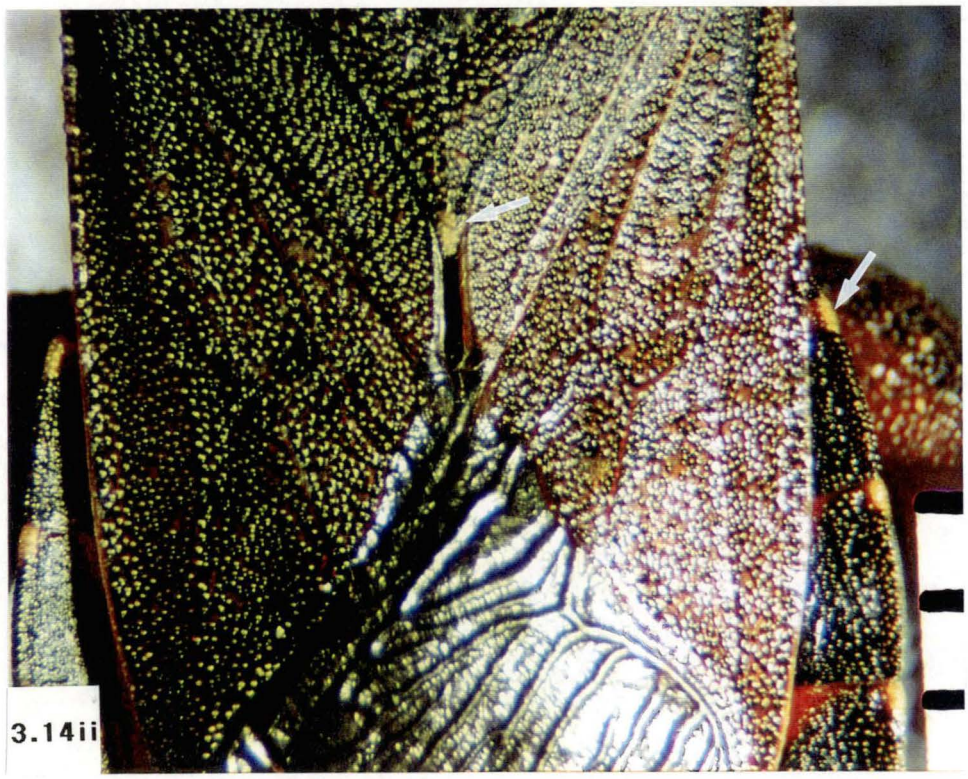
Figs 3.12i, 3.12ii. Dorsal views of: **(3.12i)** *A. bispinus*, abdomen (dark hemelytral membrane highlighted by arrow); **(3.12ii)** *A. obscuricornis*, abdomen (luteous spots on scutellum and connexivum highlighted by arrows). (Scale line interval = 1 mm.)





Figs 3.13i, 3.13ii. Dorsal views of: **(3.13i)** *A. rhombeus*, abdomen (holotype) (rhomboidal abdomen, highlighted by arrow); **(3.13ii)** *A. rhombifer*, abdomen (hemelytra nearly touching apex of abdomen, highlighted by arrow). (Scale line interval = 1 mm.)

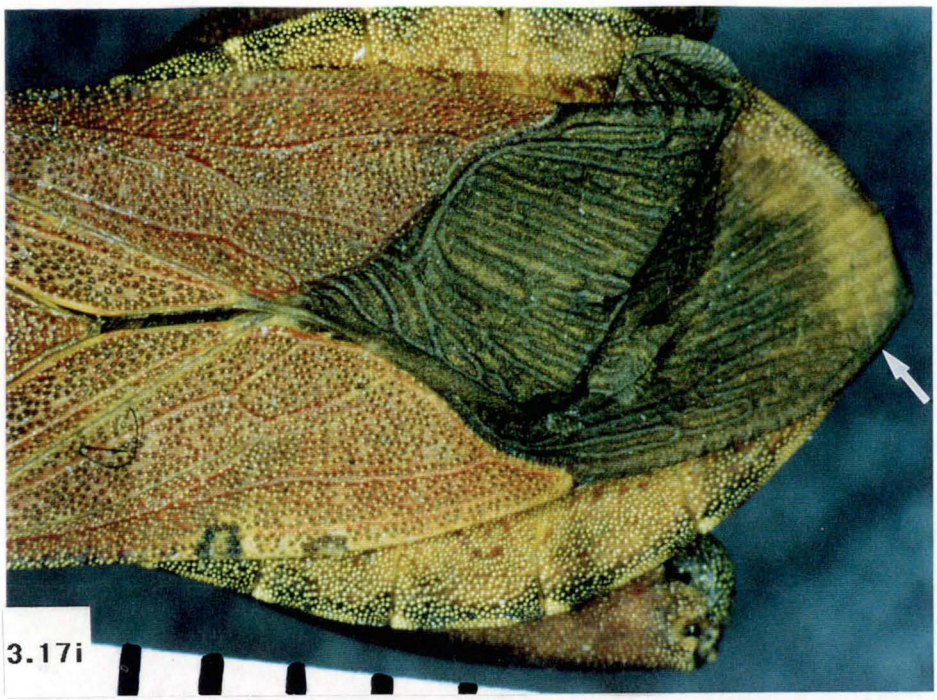


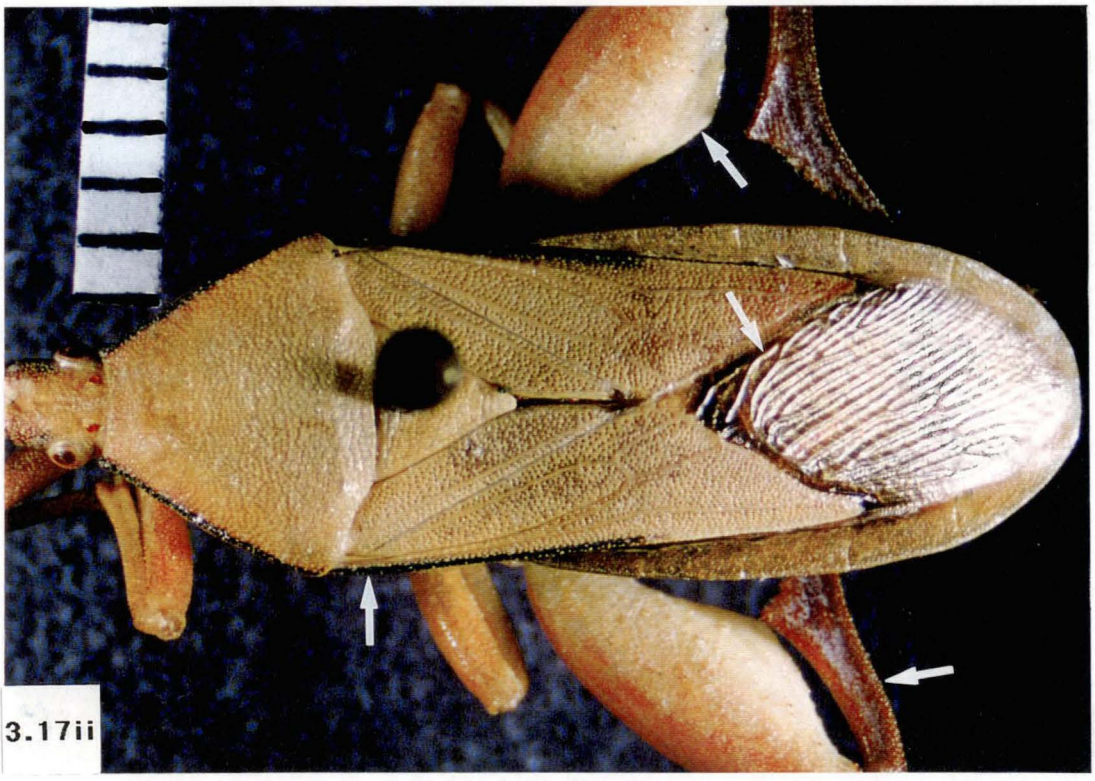


Figs 3.14i, 3.14ii. Dorsal views of: **(3.14i)** *A. robustus*, abdomen (pale region on hemelytron highlighted by arrow); **(3.14ii)** *A. rubiginosus*, abdomen (luteous spots on scutellum and connexivum highlighted by arrows). (Scale line interval = 1 mm.)

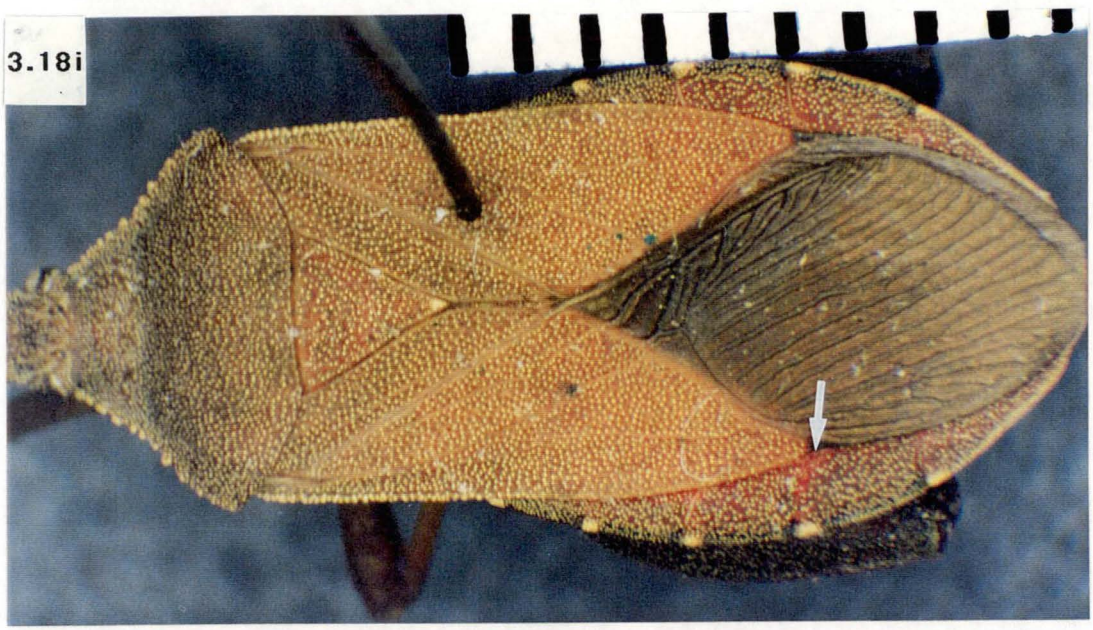
Figs 3.15i, 3.15ii. Dorsal views of: **(3.15i)** *A. subserratus*, abdomen (holotype) (luteous spots on connexivum highlighted by arrow); **(3.15ii)** *Amorbus* n. sp. 1, abdomen (rhomboidal abdomen, highlighted by arrow). (Scale line interval = 1 mm.)

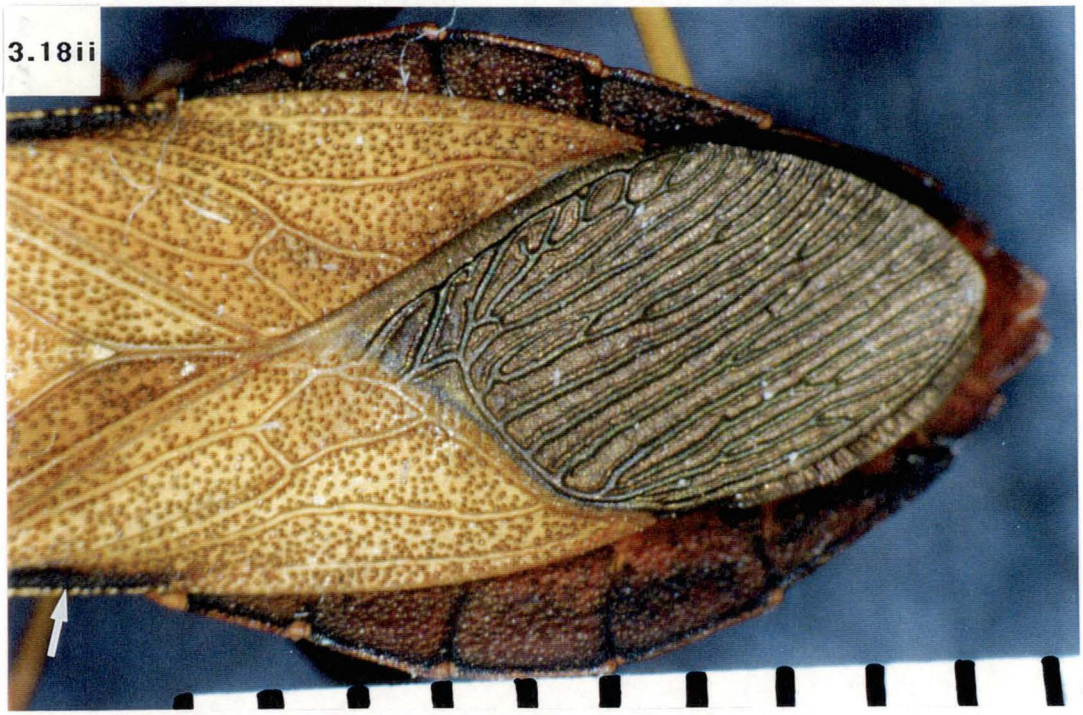
Figs 3.16i, 3.16ii. Dorsal views of: **(3.16i)** *Amorbus* n. sp. 2, body (luteous margin of pronotum highlighted by arrow); **(3.16ii)** *Amorbus* n. sp. 3, abdomen (luteous bands on connexivum highlighted by arrow). (Scale line interval = 1 mm.)



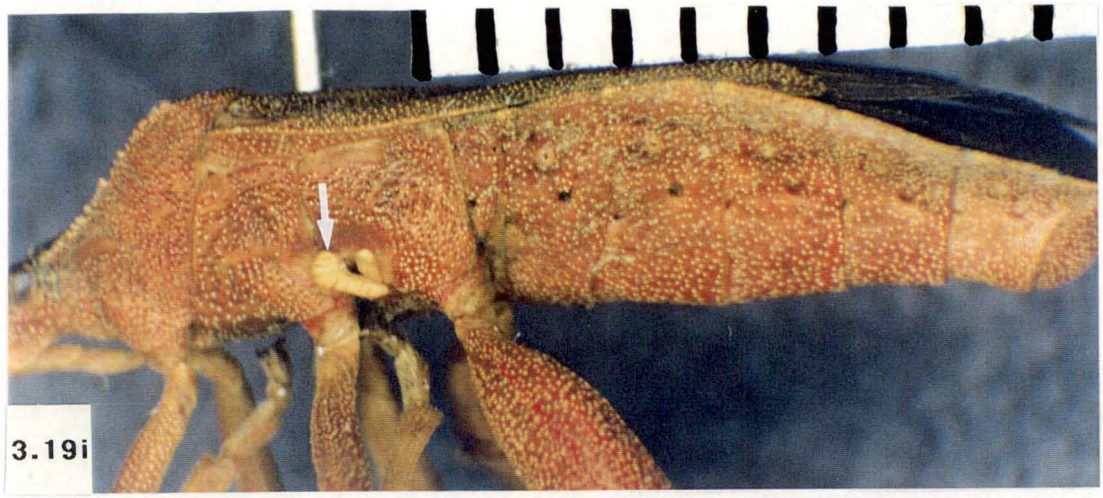


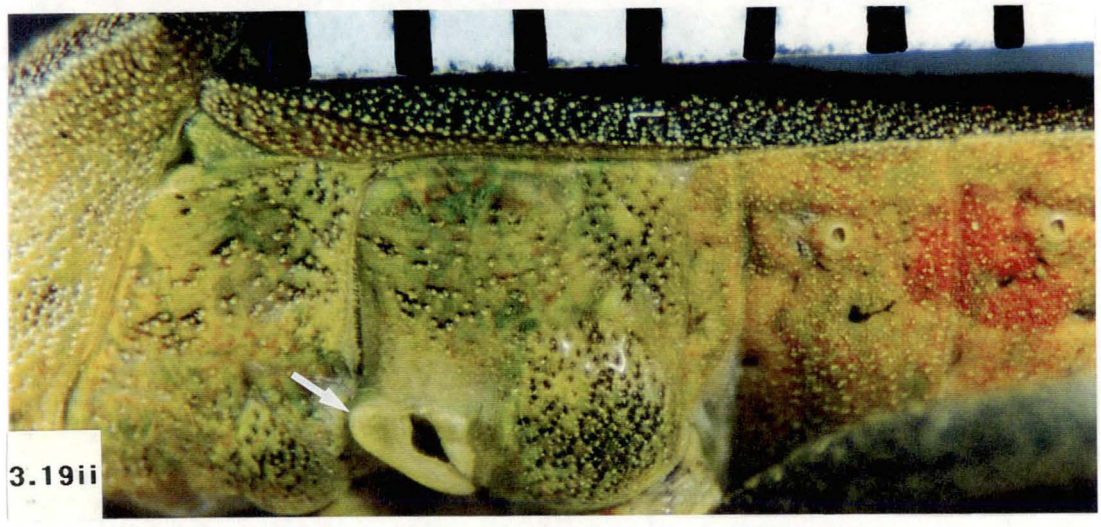
Figs 3.17i, 3.17ii. Dorsal views of: **(3.17i)** *Amorbus* n. sp. 4, abdomen (hemelytra reaching apex of abdomen, highlighted by arrow); **(3.17ii)** *Amorbus* n. sp. 5, body (luteous hind femur with low keel, brown hind tibia, hyaline hemelytral membrane and black margin of hemelytron and pronotum highlighted by arrows). (Scale line interval = 1 mm.)

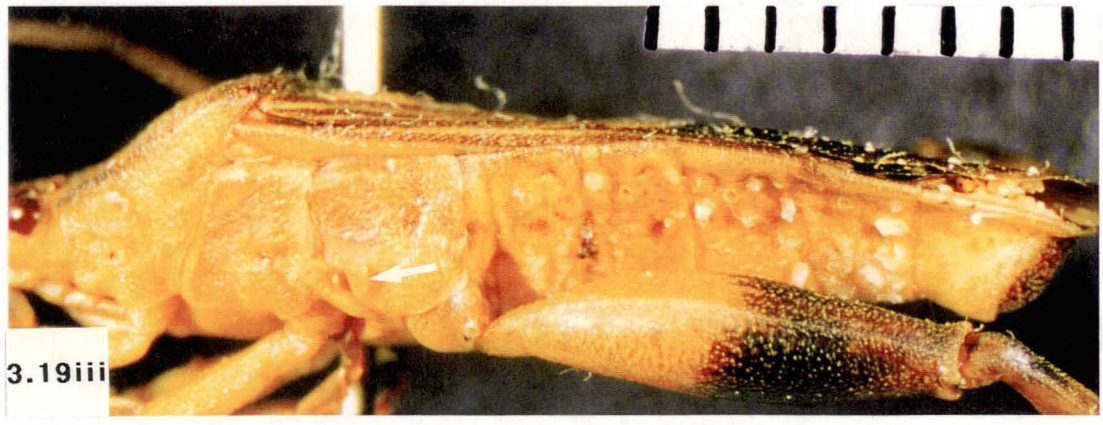




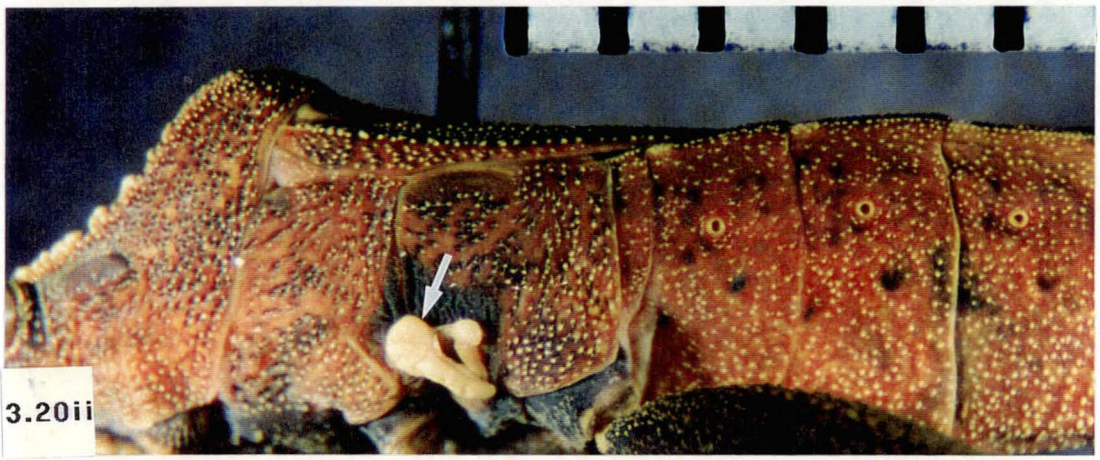
Figs 3.18i, 3.18ii. Dorsal views of: **(3.18i)** *Amorbus* n. sp. 6, body (rose coloured abdomen highlighted by arrow); **(3.18ii)** *Amorbus* n. sp. 7, adult ♀, abdomen (specimen slightly shrivelled) (black margin of hemelytron highlighted by arrow). (Scale line interval = 1 mm.)



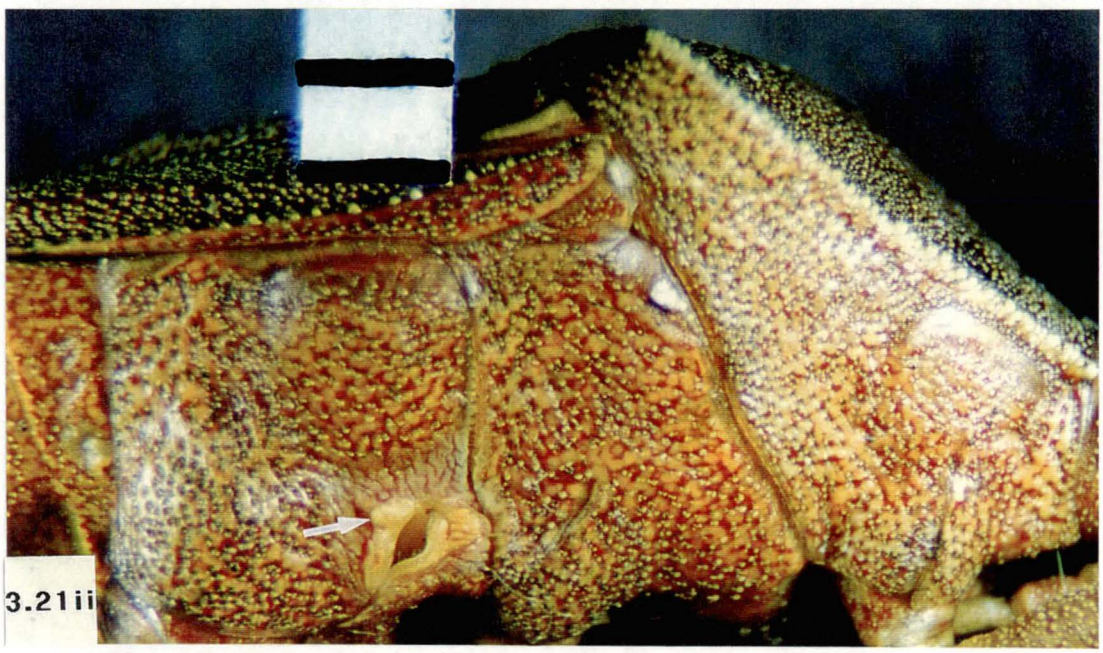




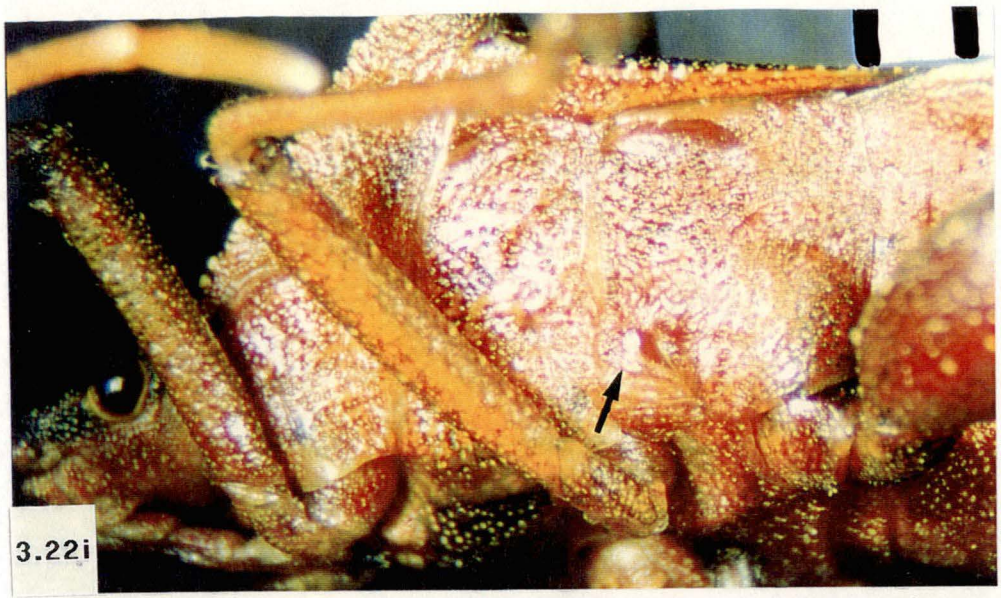
Figs 3.19i-3.19iii. Lateral views of: **(3.19i)** *A. angustior*, body (holotype) (yellow evaporatorium highlighted by arrow); **(3.19ii)** *A. atomarius*, thorax (mostly concolourous evaporatorium highlighted by arrow); **(3.19iii)** *A. biguttatus*, body (concolourous evaporatorium highlighted by arrow). (Scale line interval = 1 mm.)

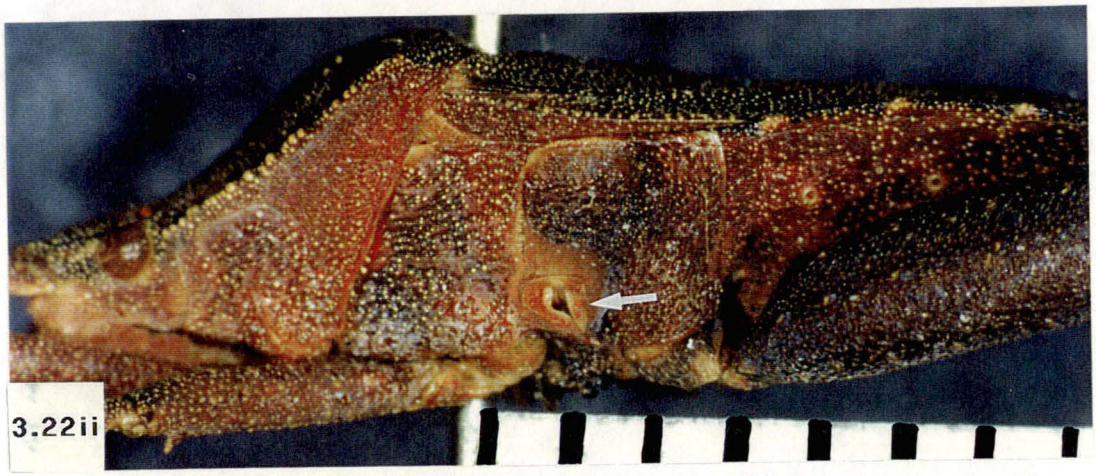


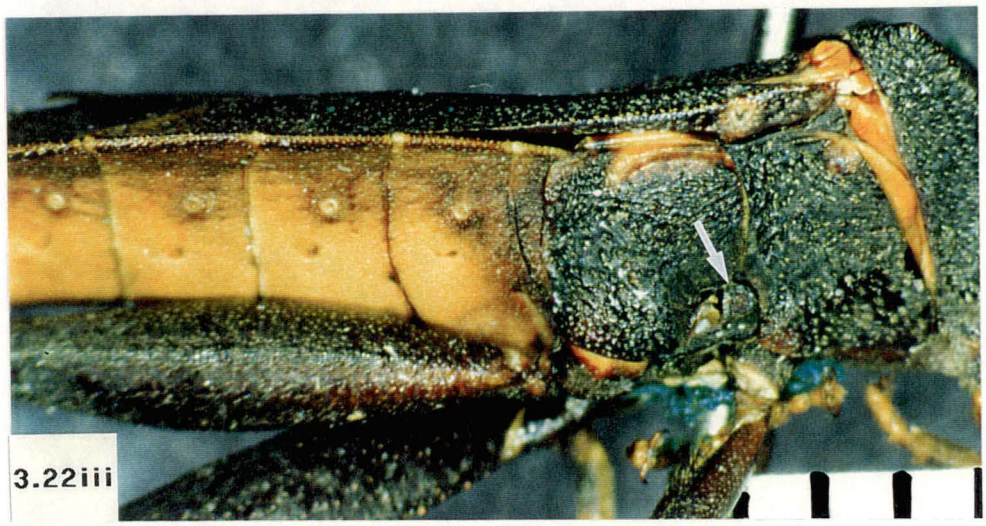
Figs 3.20i-3.20iii. Lateral views of: **(3.20i)** *A. bispinus*, thorax & abdomen (red evaporatorium highlighted by arrow); **(3.20ii)** *A. obscuricornis*, body (swollen, yellow, evaporatorium highlighted by arrow); **(3.20iii)** *A. rhombeus*, thorax & abdomen (holotype) (concolourous evaporatorium highlighted by arrow). (Scale line interval = 1 mm.)



Figs 3.21i, 3.21ii. Lateral views of: **(3.21i)** *A. rhombifer*, head & thorax (concolourous evaporatorium highlighted by arrow); **(3.21ii)** *A. robustus*, thorax (yellow evaporatorium highlighted by arrow). (Scale line interval = 1 mm.)

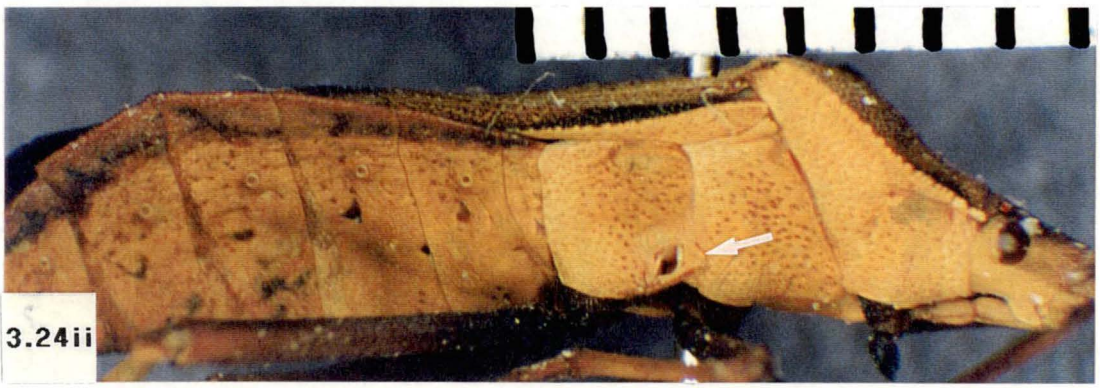




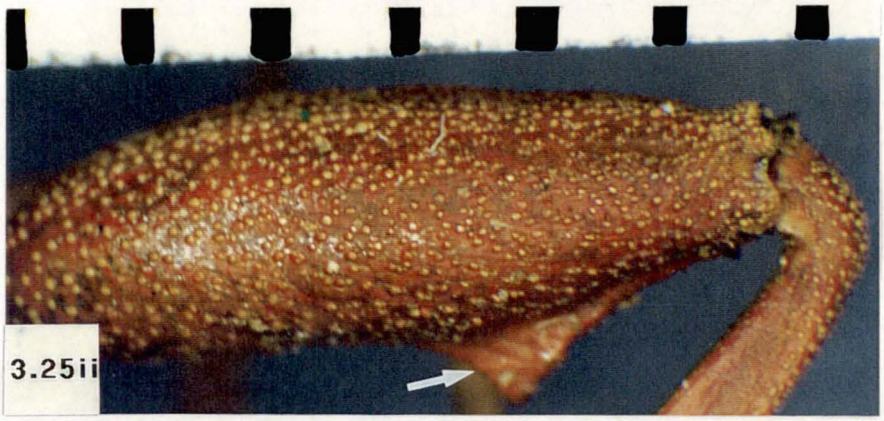


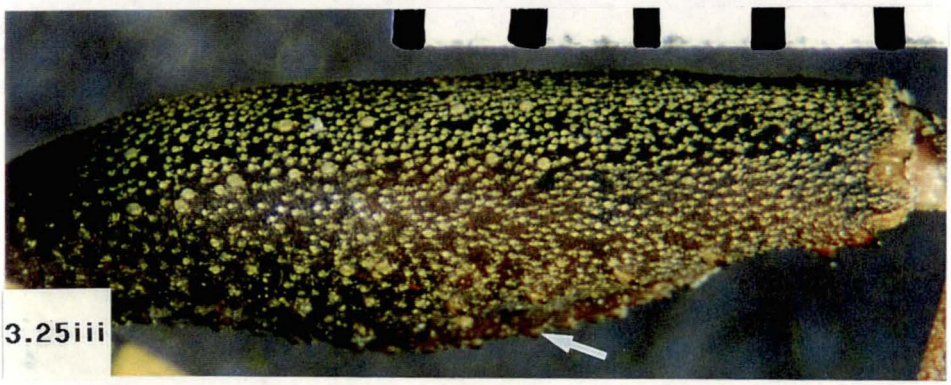
Figs 3.22i-3.22iii. Lateral views of: **(3.22i)** *A. rubiginosus*, head & thorax (mostly concolourous evaporatorium highlighted by arrow); **(3.22ii)** *A. subserratus*, body (holotype) (pale evaporatorium highlighted by arrow); **(3.22iii)** *Amorbus* n. sp. 1, thorax & abdomen (black evaporatorium highlighted by arrow). (Scale line interval = 1 mm.)

Figs 3.23i-3.23iii. Lateral views of: **(3.23i)** *Amorbus* n. sp. 2, body (pale evaporatorium highlighted by arrow); **(3.23ii)** *Amorbus* n. sp. 3, head & thorax (red evaporatorium highlighted by arrow); **(3.23iii)** *Amorbus* n. sp. 4, body (concolourous evaporatorium highlighted by arrow). (Scale line interval = 1 mm.)

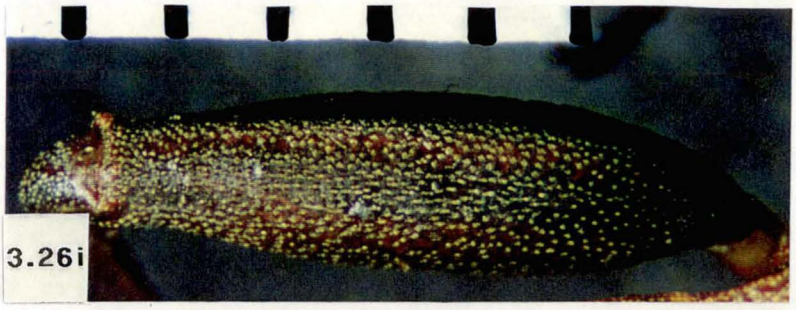


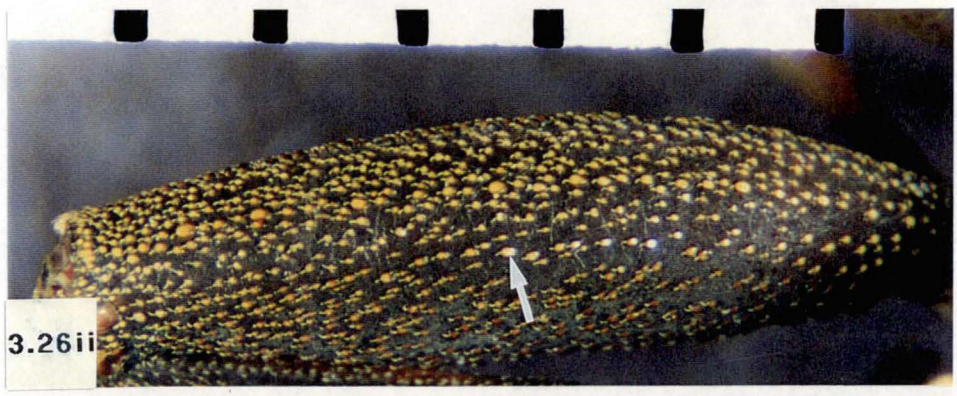
Figs 3.24i, 3.24ii. Lateral views of: **(3.24i)** *Amorbus* n. sp. 6, body (swollen, yellow, evaporatorium and rose coloured abdomen highlighted by arrows); **(3.24ii)** *Amorbus* n. sp. 7, adult ♀, body (specimen slightly shrivelled) (concolourous evaporatorium highlighted by arrow). (Scale line interval = 1 mm.)



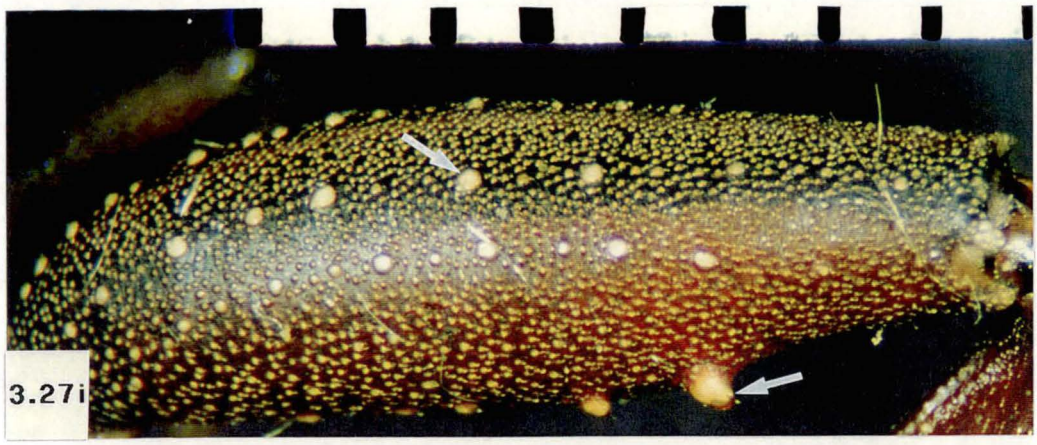


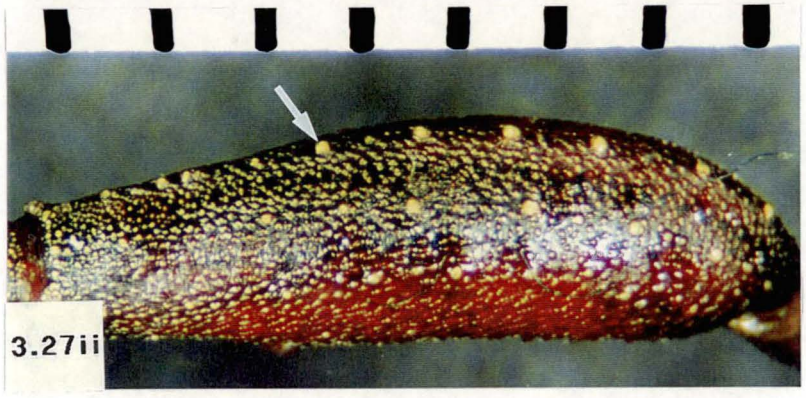
Figs 3.25i-3.25iv. Hind femora of: **(3.25i)** *A. alternatus*, dorsal (obvious macula and yellow spine highlighted by arrows); **(3.25ii)** *A. angustior*, dorsal (holotype) (triangular keel highlighted by arrow); **(3.25iii)** *A. atomarius*, dorsal (small spine highlighted by arrow); **(3.25iv)** *A. biguttatus*, dorsal (small spine highlighted by arrow). (Scale line interval = 1 mm.)

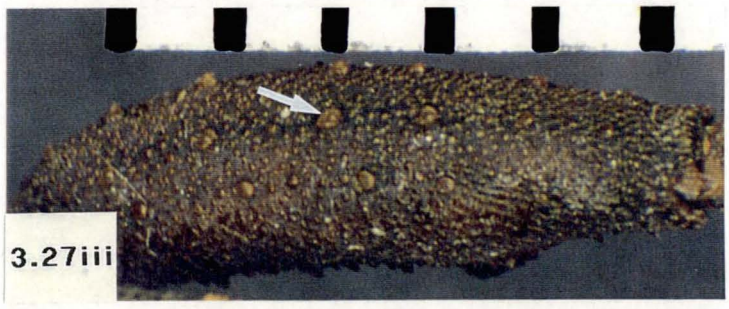


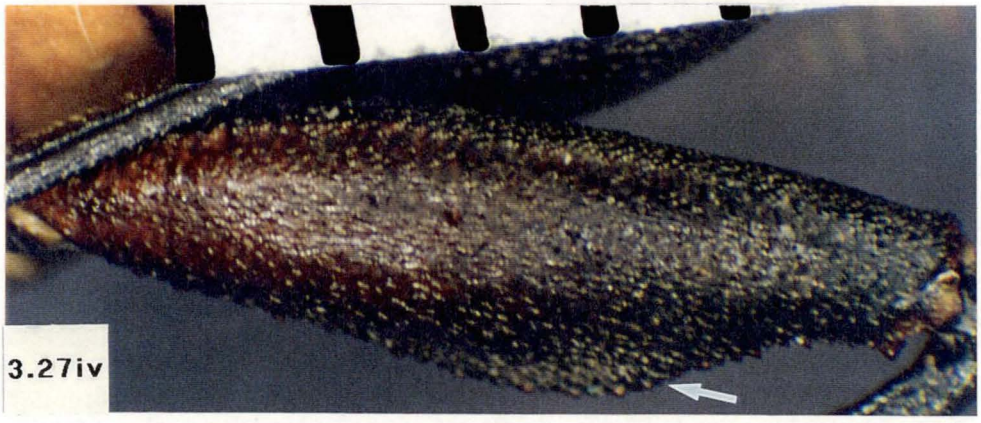


Figs 3.26i-3.26iv. Hind femora of: **(3.26i)** *A. bispinus*, dorsal; **(3.26ii)** *A. obscuricornis*, dorsal (small macula highlighted by arrow); **(3.26iii)** *A. rhombeus*, ventral (holotype) (low keel highlighted by arrow); **(3.26iv)** *A. rhombifer*, dorsal. (Scale line interval = 1 mm.)

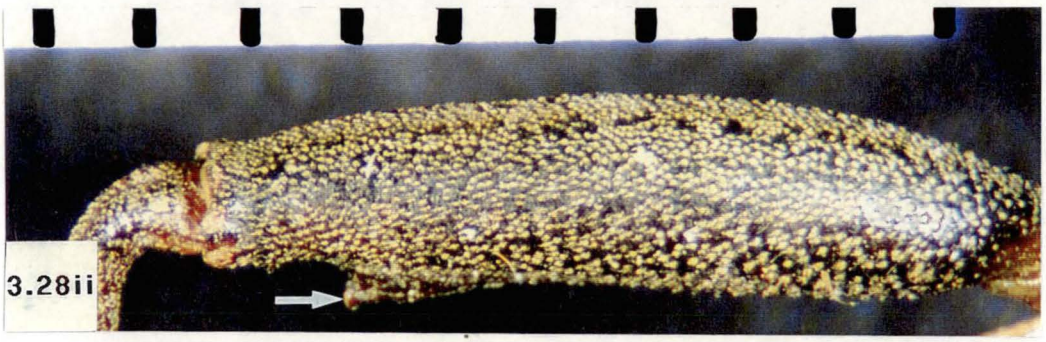


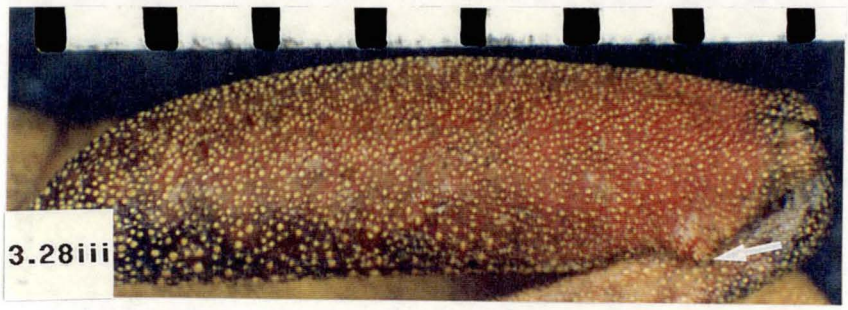


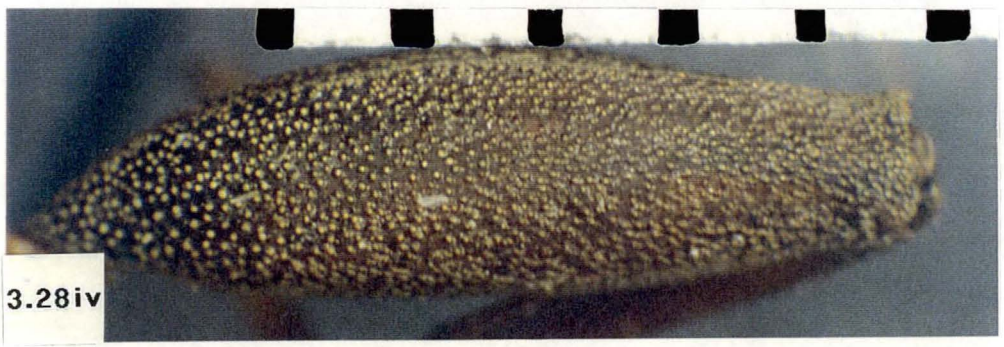


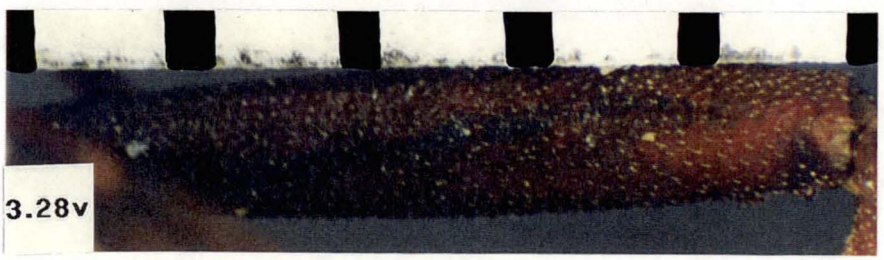


Figs 3.27i-3.27iv. Hind femora of: **(3.27i)** *A. robustus*, dorsal (obvious macula and luteous spine highlighted by arrows); **(3.27ii)** *A. rubiginosus*, dorsal (obvious macula highlighted by arrow); **(3.27iii)** *A. subserratus*, dorsal (holotype) (obvious macula highlighted by arrow); **(3.27iv)** *Amorbus* n. sp. 1, ventral (low keel highlighted by arrow). (Scale line interval = 1 mm.)

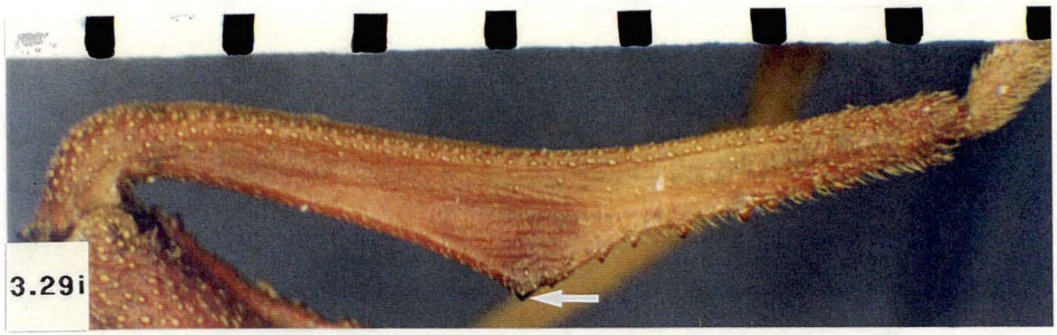


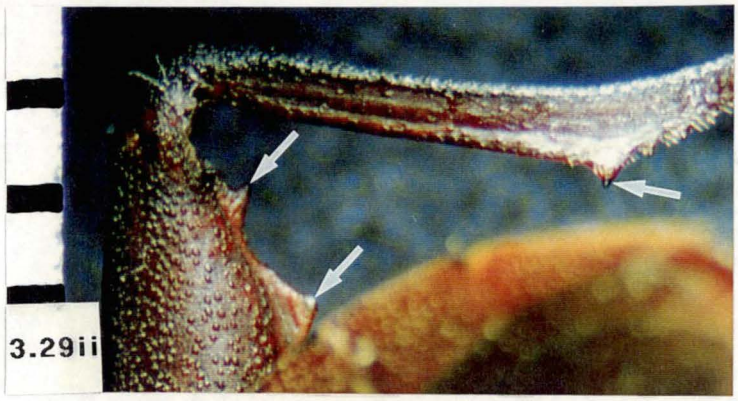


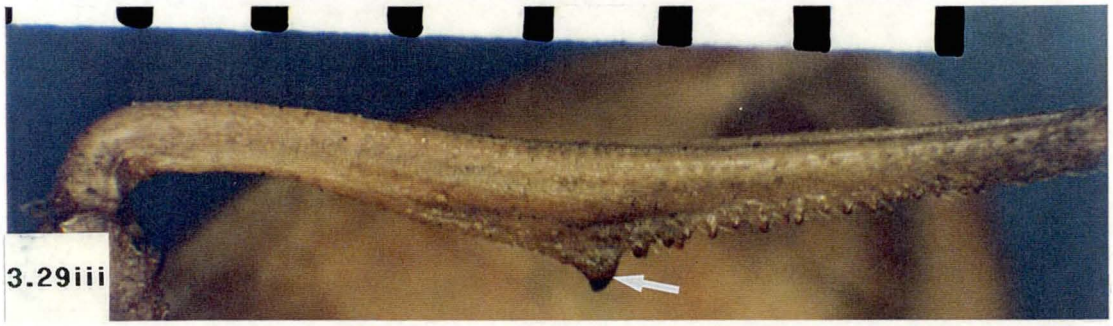


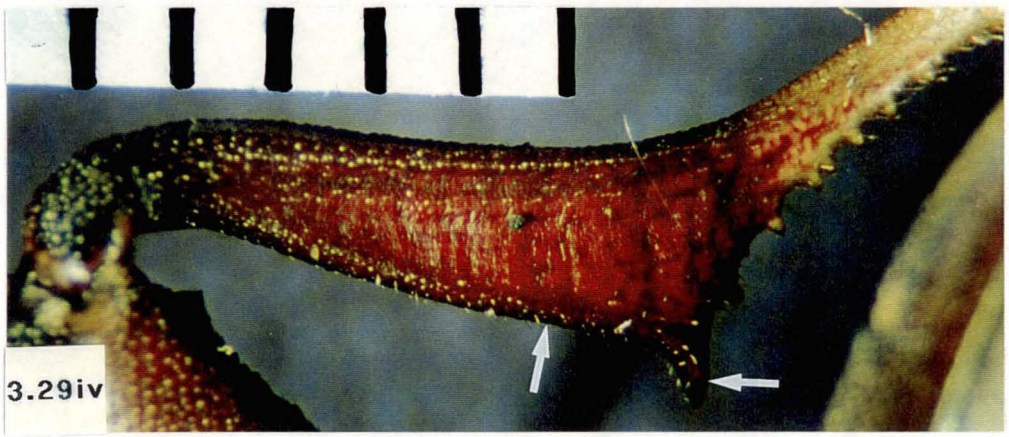


Figs 3.28i-3.28v. Hind femora of: **(3.28i)** *Amorbus* n. sp. 2, dorsal (obvious macula highlighted by arrow); **(3.28ii)** *Amorbus* n. sp. 3, dorsal (flattened spine highlighted by arrow); **(3.28iii)** *Amorbus* n. sp. 4, ventral (small spine highlighted by arrow); **(3.28iv)** *Amorbus* n. sp. 6, dorsolateral; **(3.28v)** *Amorbus* n. sp. 7, adult ♀, dorsal. (Scale line interval = 1 mm.)

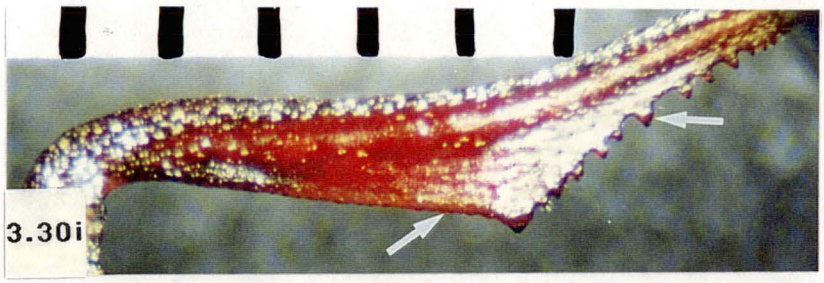


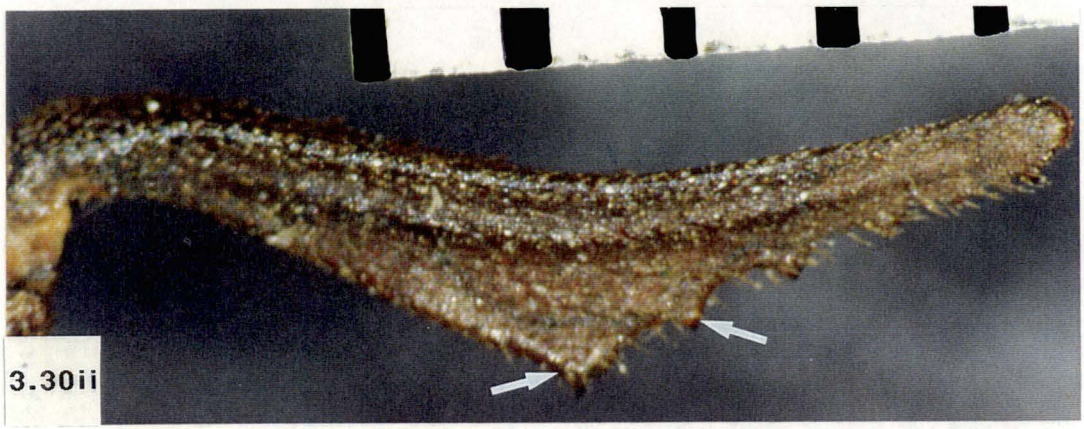


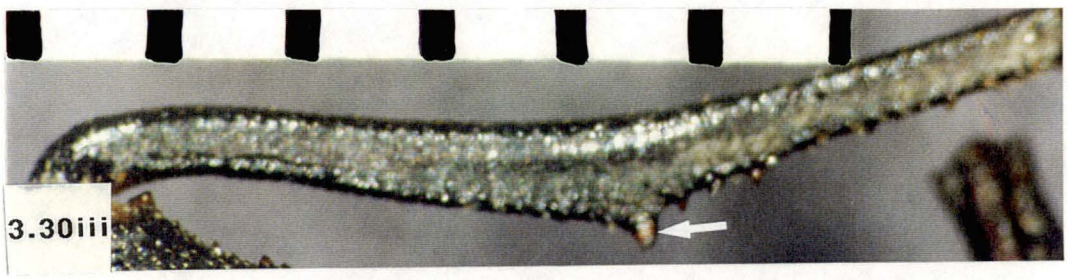


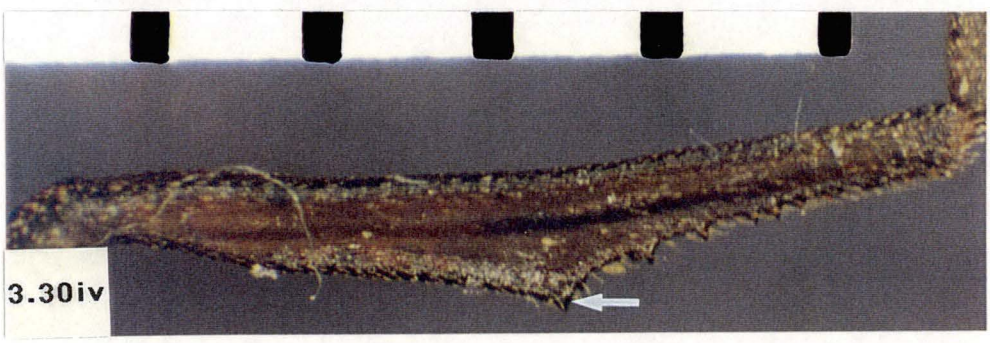


Figs 3.29i-3.29iv. Hind tibiae of: **(3.29i)** *A. angustior*, dorsal (holotype) (flattened medial keel highlighted by arrow); **(3.29ii)** *A. bispinus*, dorsal (flattened spines on femur and tibia highlighted by arrows); **(3.29iii)** *A. rhombeus*, ventral (holotype) (flattened medial spine highlighted by arrow); **(3.29iv)** *A. robustus*, dorsal (flattened keel and medial spine highlighted by arrows). (Scale line interval = 1 mm.)

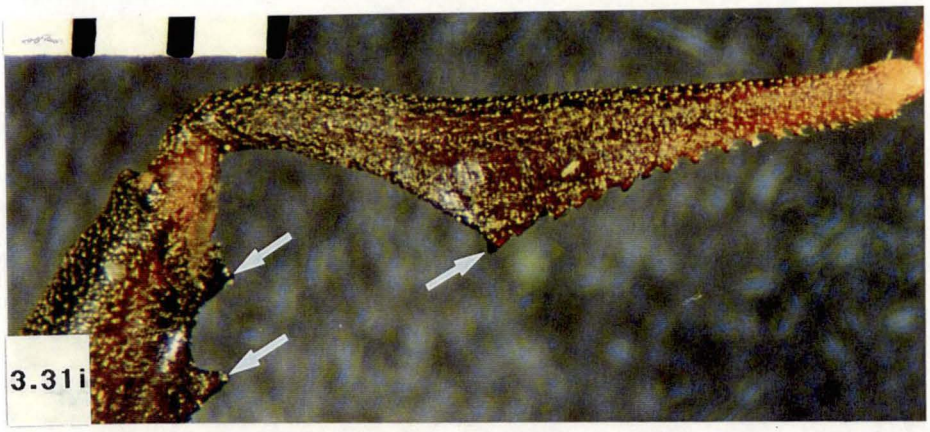


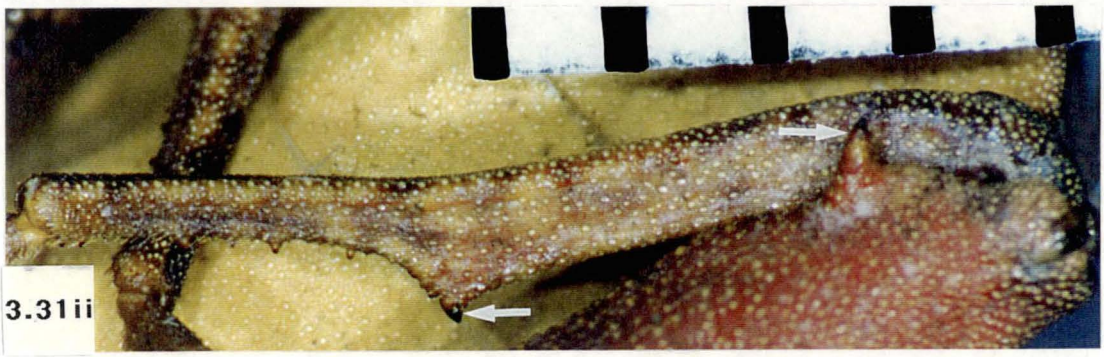


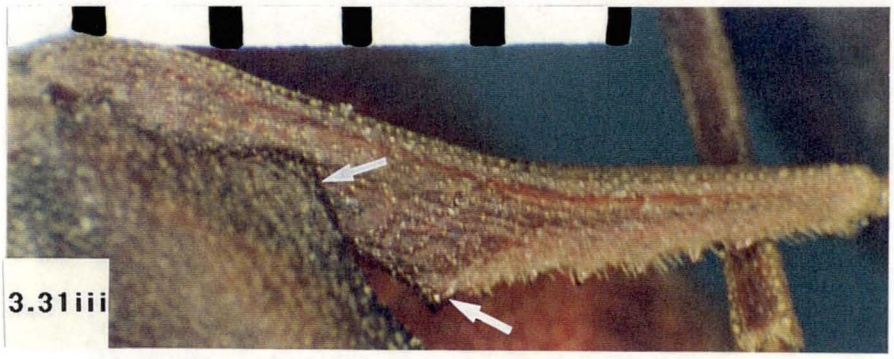




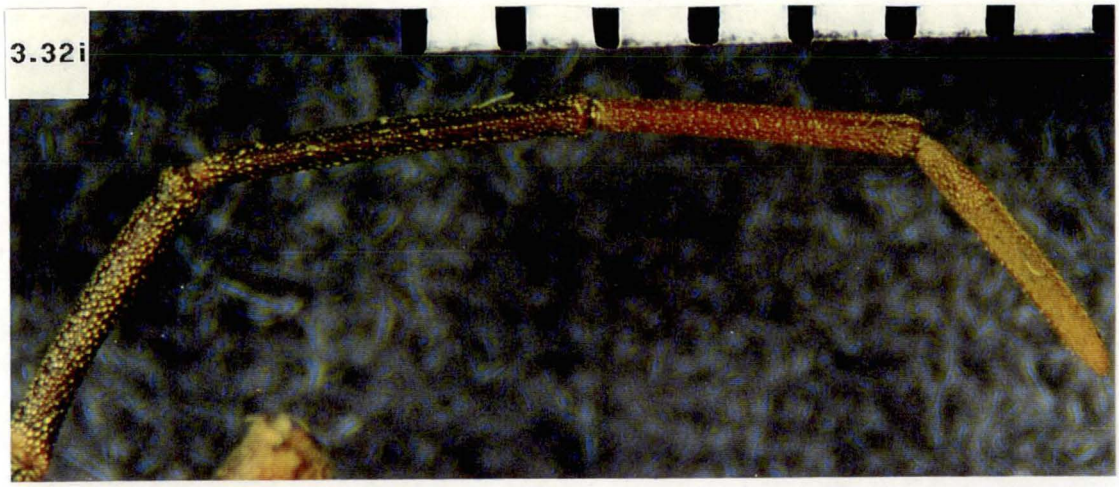
Figs 3.30i-3.30iv. Hind tibiae of: **(3.30i)** *A. rubiginosus*, dorsal (flattened, medial, spine and tibial serrations highlighted by arrows); **(3.30ii)** *A. subserratus*, dorsal (holotype) (flattened keel with medial spine and tibial serrations highlighted by arrows); **(3.30iii)** *Amorbus* n. sp. 1, ventral (medial spine highlighted by arrow); **(3.30iv)** *Amorbus* n. sp. 2, dorsal (flattened, medial, spine highlighted by arrow). (Scale line interval = 1 mm.)

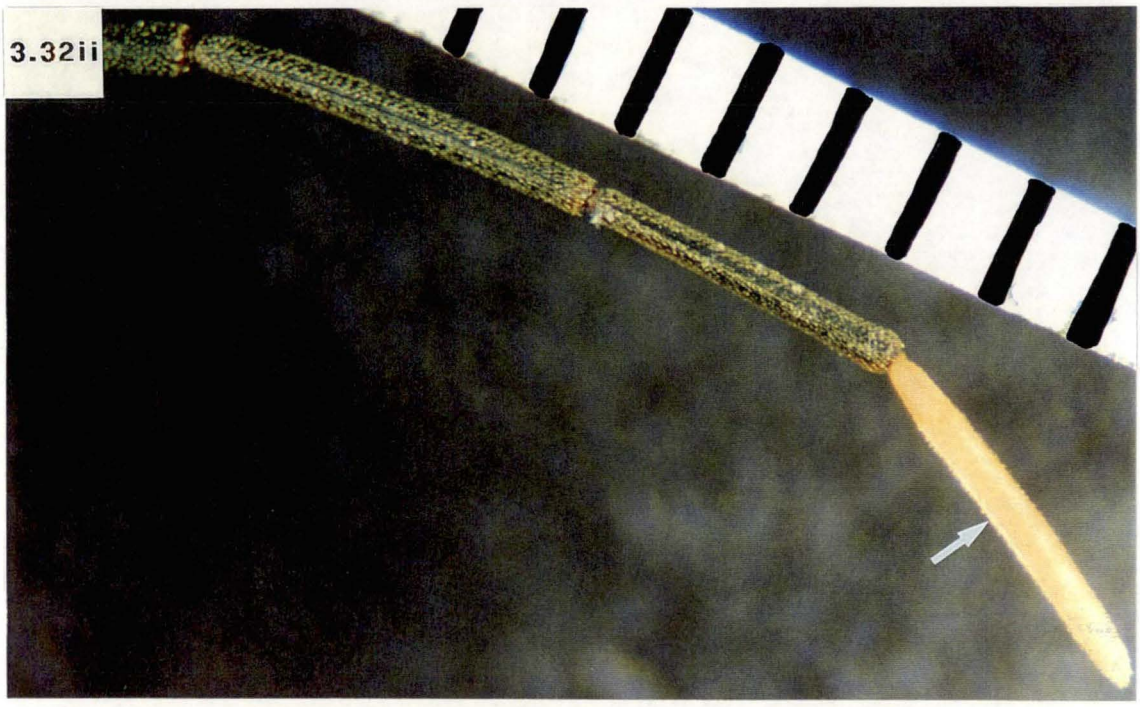




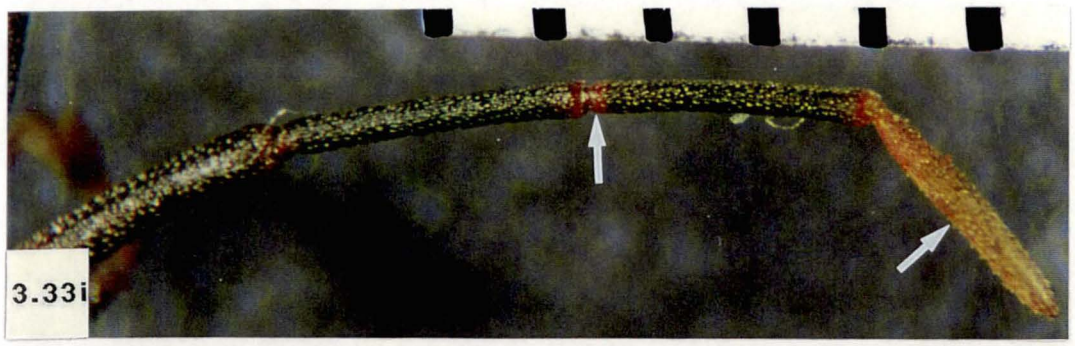


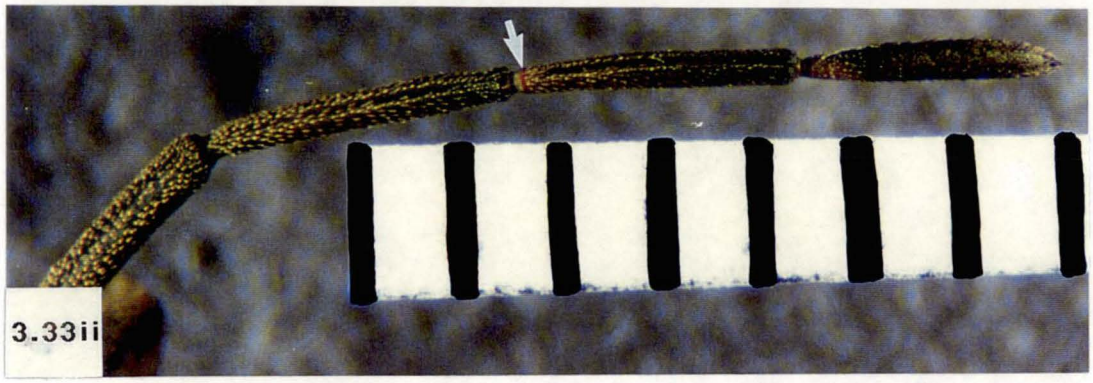
Figs 3.31i-3.31iii. Hind tibiae of: **(3.31i)** *Amorbus* n. sp. 3, dorsal (flattened spines on femur and medial spine on tibia highlighted by arrows); **(3.31ii)** *Amorbus* n. sp. 4, ventral (spine on femur and atop medial keel on tibia highlighted by arrows); **(3.31iii)** *Amorbus* n. sp. 6, ventral (triangular keel on femur and medial keel on tibia highlighted by arrows). (Scale line interval = 1 mm.)

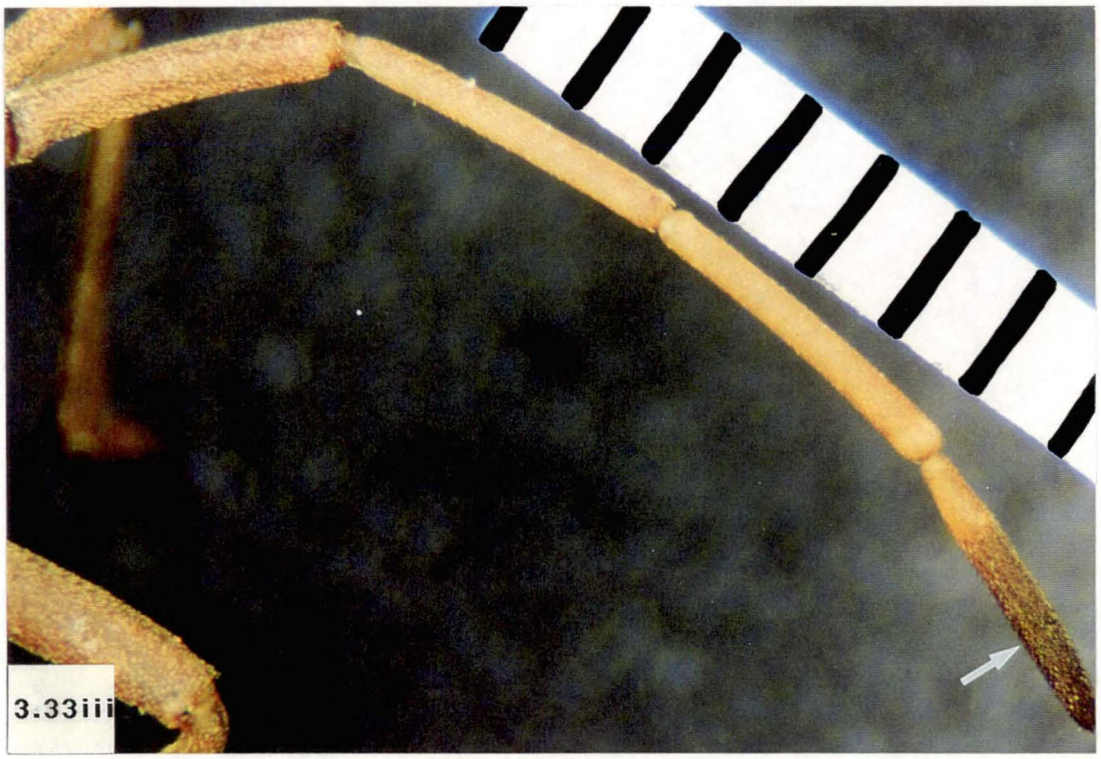




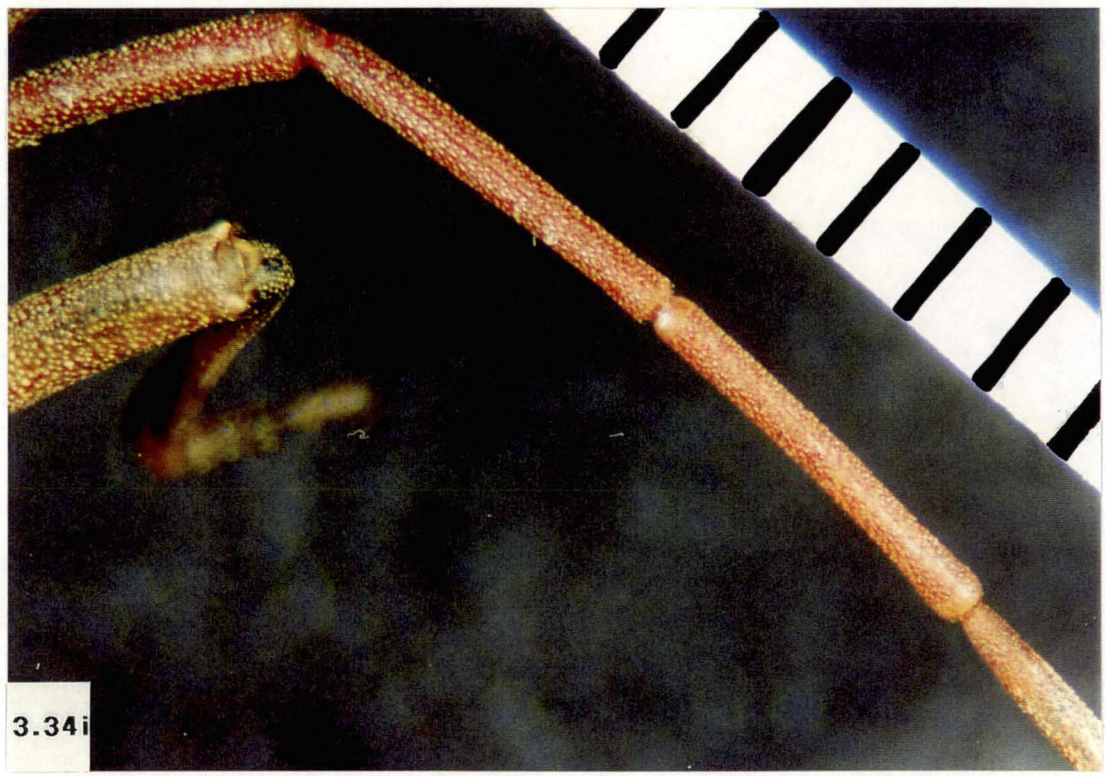
Figs 3.32i-3.32iii. Dorsal view of the antennae of: **(3.32i)** *A. alternatus*; **(3.32ii)** *A. atomarius* (yellow antennal segment IV highlighted by arrow); **(3.32iii)** *A. biguttatus* (pale yellow, distal, ¾ of antennal segment IV highlighted by arrow). (Scale line interval = 1 mm.)

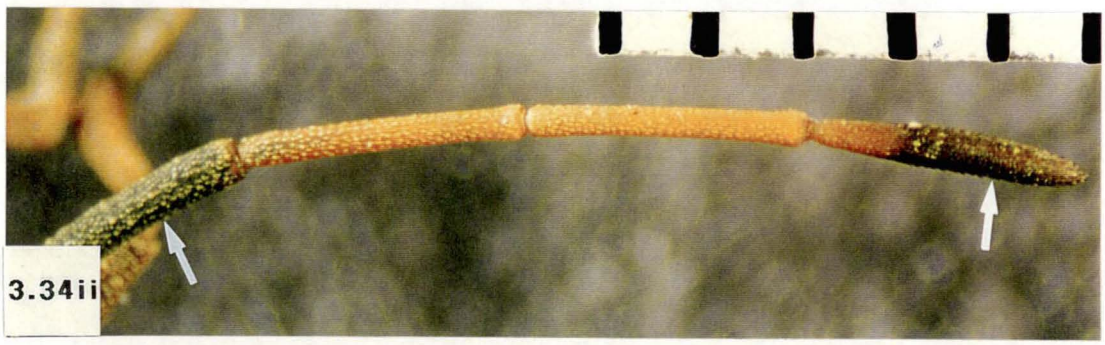


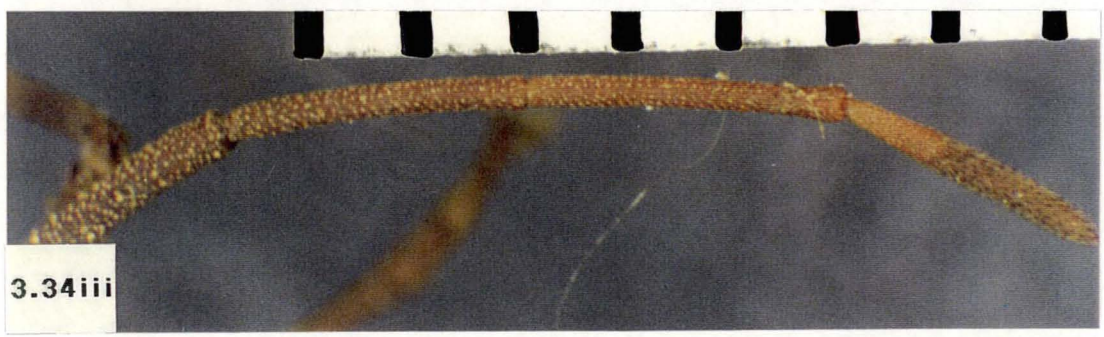




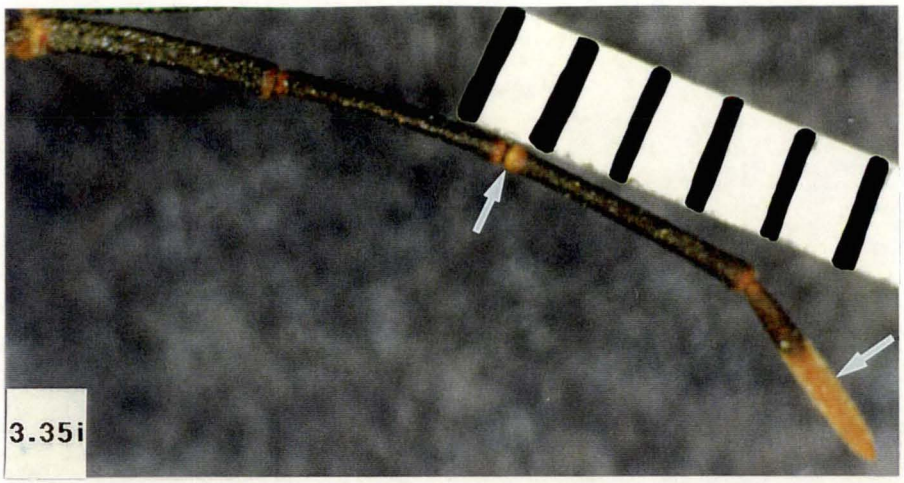
Figs 3.33i-3.33iii. Dorsal view of the antennae of: **(3.33i)** *A. bispinus* (red joint and brown antennal segment IV highlighted by arrows); **(3.33ii)** *A. obscuricornis* (pale joint highlighted by arrow); **(3.33iii)** *A. rhombifer* (dark ¾ of antennal segment IV highlighted by arrow). (Scale line interval = 1 mm.)

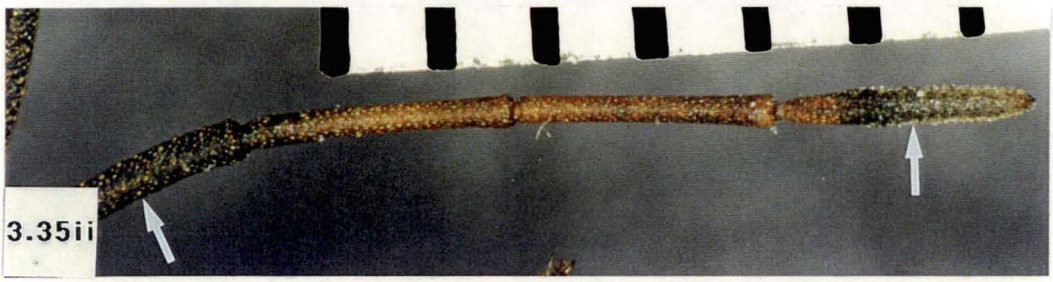


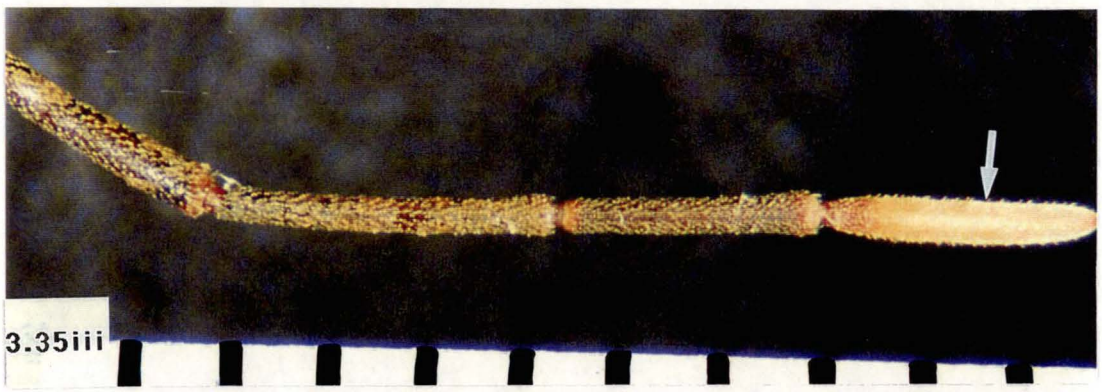


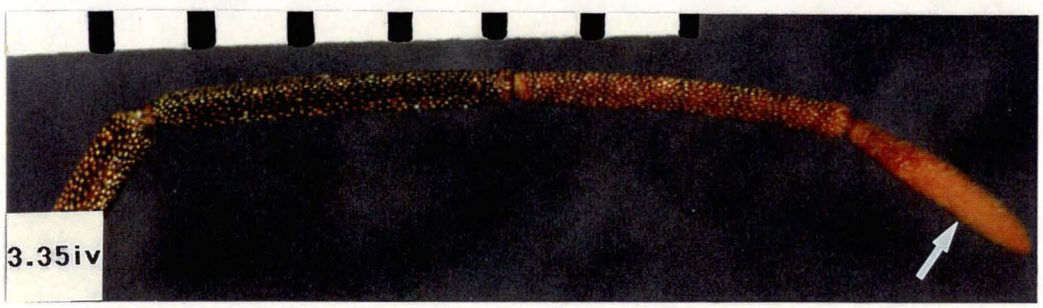


Figs 3.34i-3.34iii. Dorsal view of the antennae of: **(3.34i)** *A. robustus*; **(3.34ii)** *A. rubiginosus* (dark antennal segment I and dark ¾ of antennal segment IV highlighted by arrows); **(3.34iii)** *A. subserratus* (holotype). (Scale line interval = 1 mm.)

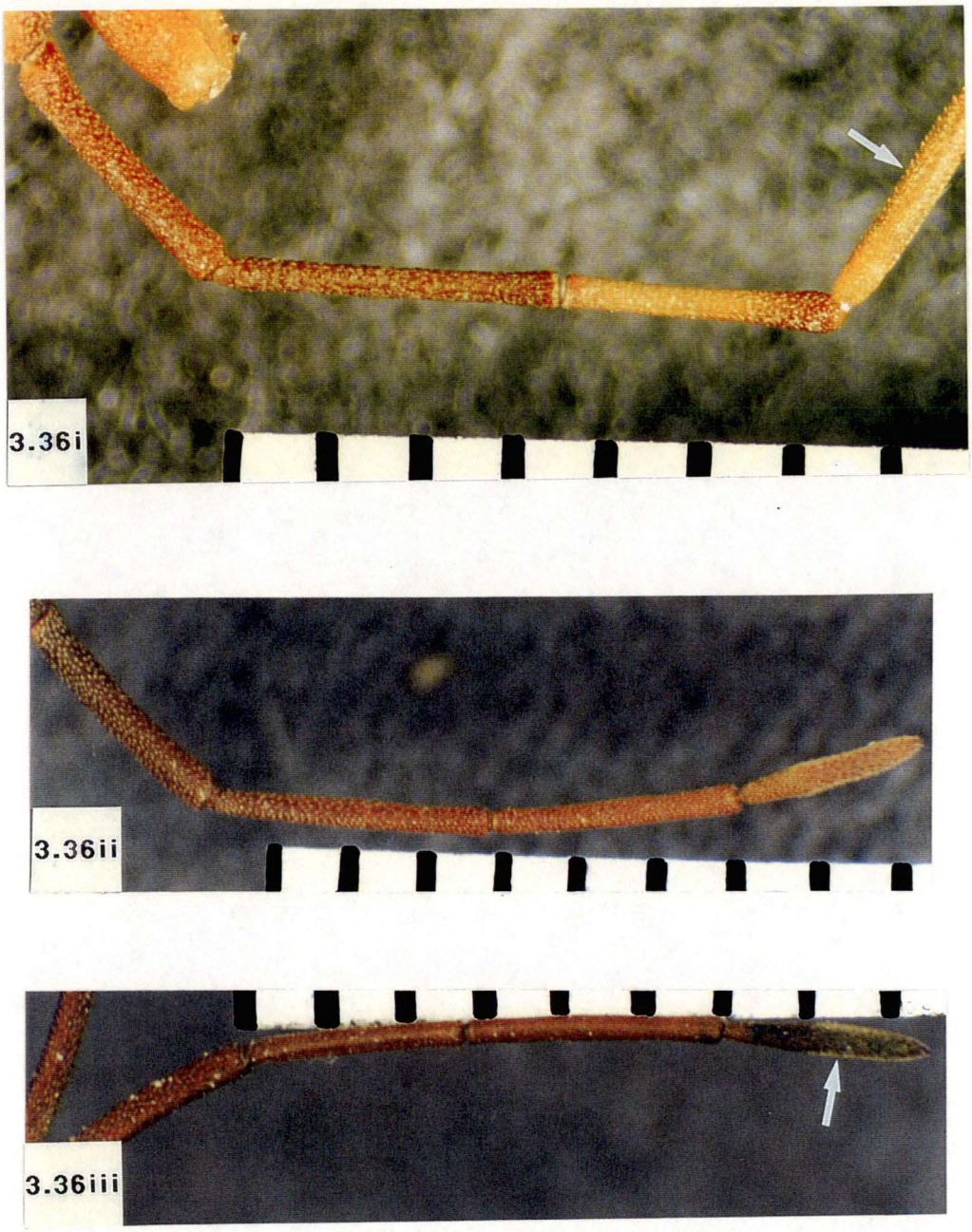








Figs 3.35i-3.35iv. Dorsal view of the antennae of: **(3.35i)** *Amorbus* n. sp. 1 (luteous joint and distal ⅔ of antennal segment IV highlighted by arrow); **(3.35ii)** *Amorbus* n. sp. 2 (dark antennal segment I and dark ¾ of antennal segment IV highlighted by arrows); **(3.35iii)** *Amorbus* n. sp. 3 (pale yellow ¾ of antennal segment IV highlighted by arrow); **(3.35iv)** *Amorbus* n. sp. 4 (luteous ¾ of antennal segment IV highlighted by arrow). (Scale line interval = 1 mm.)



Figs 3.36i-3.36iii. Dorsal view of the antennae of: **(3.36i)** *Amorbus* n. sp. 5 (luteous antennal segment IV highlighted by arrow); **(3.36ii)** *Amorbus* n. sp. 6; **(3.36iii)** *Amorbus* n. sp. 7, adult ♀ (dark ¾ of antennal segment IV highlighted by arrow). (Scale line interval = 1 mm.)

Figs 3.37i-3.37viii. Scanning electron micrographs of *A. obscuricornis*: **(3.37i)** apex of fourth antennal segment, adult ♂; **(3.37ii)** basal quarter of fourth antennal segment, adult ♂; **(3.37iii)** apex of fourth antennal segment, adult ♀; **(3.37iv)** basal quarter of fourth antennal segment, adult ♀; **(3.37v)** apex of rostrum, ventral surface, adult ♂; **(3.37vi)** micro-structure of evaporatorium, adult ♂; **(3.37vii)** maculae on ventral surface of hind femur, adult ♂; **(3.37viii)** maculae on dorsal surface of hind femur, adult ♂.

I
II
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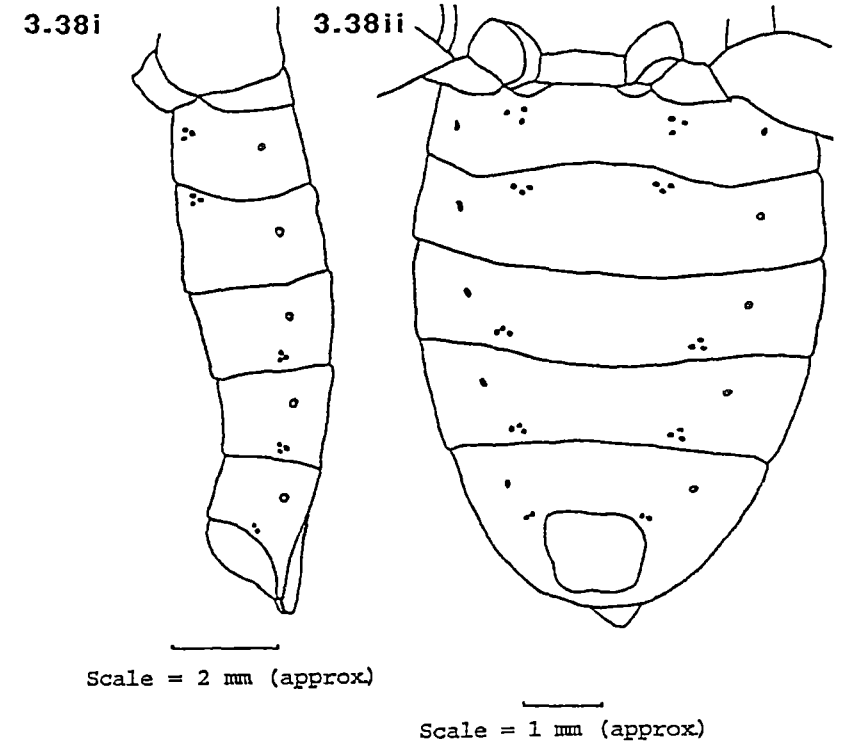
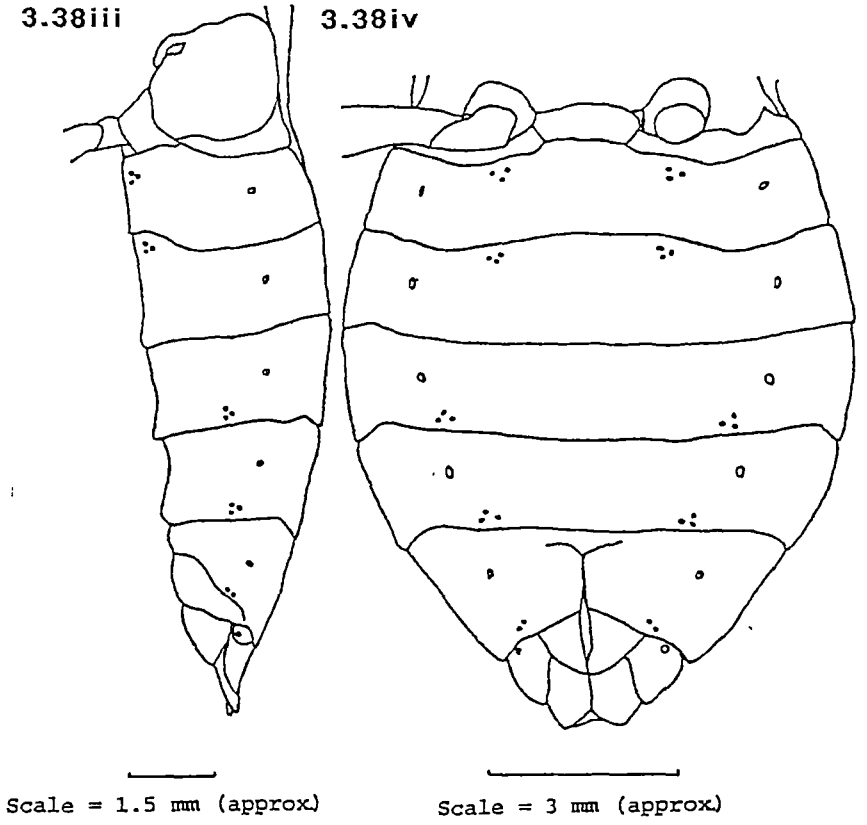
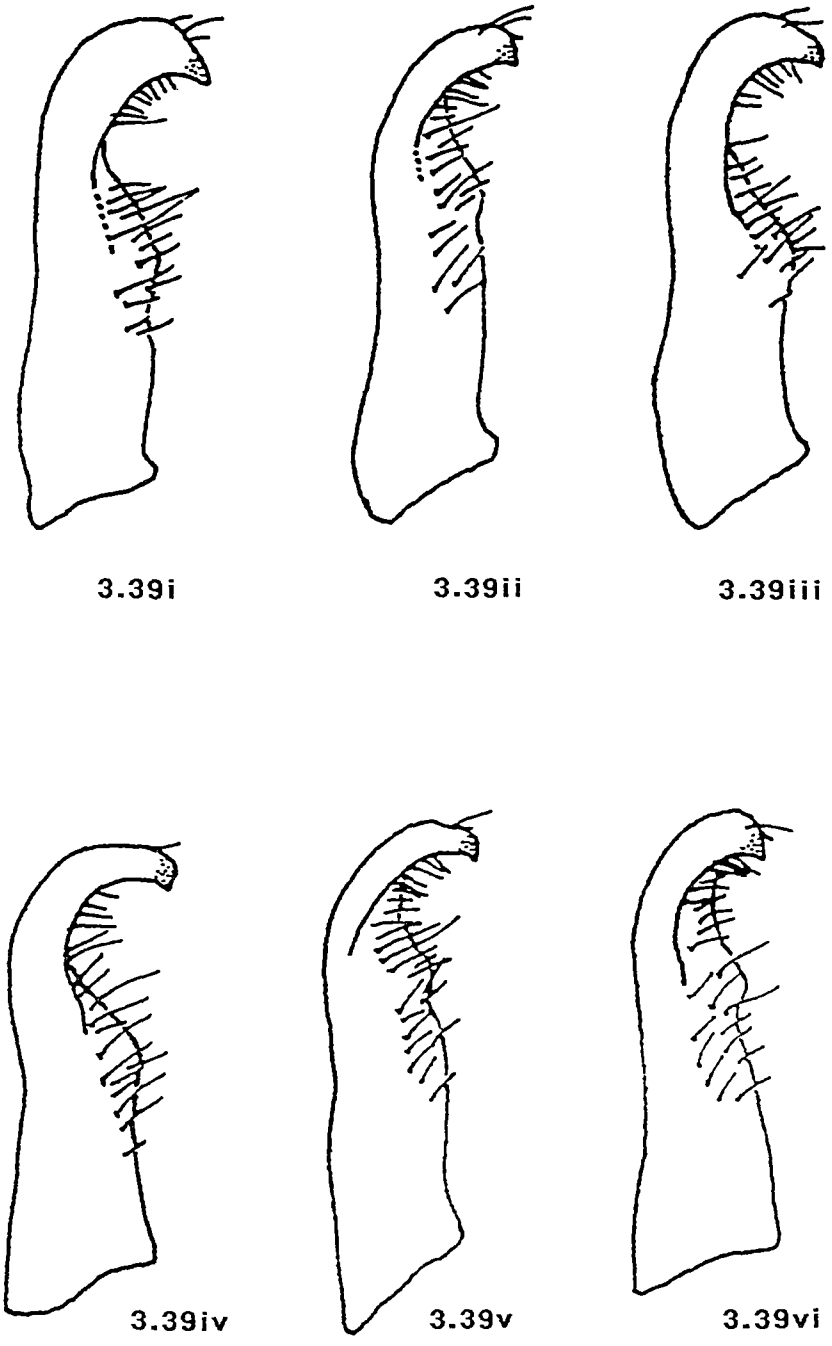
VIII





Figs 3.38i-3.38iv. *A. obscuricornis*: **(3.38i)** abdomen of adult ♂, lateral aspect; **(3.38ii)** abdomen of adult ♂, ventral aspect; **(3.38iii)** abdomen of adult ♀, lateral aspect; **(3.38iv)** abdomen of adult ♀, ventral aspect.



Figs 3.39i-3.39vi. Parameres of: **(3.39i)** "*A. obscuricornis* mainland" from Jenolan State Forest (N.S.W.) 29/12/1968; **(3.39ii)** "*A. obscuricornis* mainland" from Mt. Kosciusko (N.S.W.) 17/12/1953; **(3.39iii)** "*A. obscuricornis* mainland" from Hampton (N.S.W.) 27/12/1968; **(3.39iv)** "*A. obscuricornis* Tasmania" from Ridgeway 15/3/1994; **(3.39v)** "*A. obscuricornis* Tasmania" from Brooks Bay 18/3/1993; **(3.39vi)** "*A. obscuricornis* Tasmania" Darcy Link Rd. 21/4/1994.

Table 3.4. Presence or absence of sexually dimorphic hind femora and large, luteous, maculae on the hind femora for species within the genera *Gelonus*, *Acantholybas* and *Amorbus*.

Species	Sexually dimorphic hind femora	Hind femora with large, raised, maculae
G. tasmanicus	Absent	Absent
A. longulus	Absent	Absent
A. brunneus	Absent	Absent
A. kirkaldyi	Absent	Absent
A. abdominalis	Unknown	Unknown
A. alternatus	Present	Present
A. angustior	Present	Absent
A. atomarius	Present	Present§
A. biguttatus	Present	Absent
A. bispinus	Present	Absent
A. hirticulus	Present*	Unknown
A. obscuricornis	Present	Absent
A. rhombeus	Present	Absent
A. rhombifer	Present	Absent
A. robustus	Present	Present
A. rubiginosus	Present	Present
A. subserratus	Unknown	Present‡
Amorbus n. sp. 1	Present	Absent
Amorbus n. sp. 2	Present	Present
Amorbus n. sp 3	Present	Absent
Amorbus n. sp. 4	Present	Absent
Amorbus n. sp. 5	Present	Absent
Amorbus n. sp. 6	Present	Absent
Amorbus n. sp. 7	Unknown¥	Absent¥

§ maculae not as large as those found in *A. alternatus*.
* ♂ holotype possesses incrassate hind femora (G. Gross 1969 *in lit.*).
‡ the large maculae of the ♂ holotype are not as pale as in other species.
¥ only ♀ specimens of this species have been examined to-date.

3.4. *Discussion*

3.4i. The Number of Coreid Species Present in Tasmania.

This study has confirmed the existence of three coreid genera within Tasmania (as given in Semmens *et al.* 1992). Of these *Acantholybas* and *Gelonus* comprise one Tasmanian species each, namely *A. kirkaldyi* and *G. tasmanicus*. *Acantholybas* has been shown to consist of three species in total (see Steinbauer and Clarke in review) whilst *Gelonus* is represented by a single species. No evidence for a second species of *Gelonus* (as suggested by Morrow 1977b) has been found. I presently consider that in Tasmania *Amorbus* is represented by a single species, *A. obscuricornis*. As I argue below there is no evidence to suggest that *A. rubiginosus* is represented in the state as given in Semmens *et al.* (1992). In addition, I consider *A. angustior* to be conspecific with *A. obscuricornis*.

The morphometric study of adults of *A. obscuricornis* supports this proposition as the only separation of individuals that was apparent using PCA analysis was that of males and females. This study also demonstrated that differences observed in the morphology of male and female *A. obscuricornis* adults become apparent prior to eclosion (Table 3.3). The SEM study demonstrated that "*A. obscuricornis* Tasmania" had features of identical appearance to "*A. obscuricornis* mainland", as did the comparison of parameres. On the basis of examination of the type specimens and the above studies, I consider it likely that *A. obscuricornis* and *A. angustior* are conspecific. *A. rubiginosus* is a unique and easily identified species, no specimens of which were recorded as having been collected from Tasmania.

According to Dr Gross (*in lit.*) when required to choose between two species names which are synonymous it is usual practice, although not mandatory, to give precedence on the basis of page priority. Thus, as *A. angustior* was described before *A. obscuricornis* in Westwood's work, the former name should be used in preference to the latter. I have not followed this precedence as I recognise that a formal revision of the genus may find these two species are indeed unique. Given that the type locality of *A. obscuricornis* is "Van Diemens Land" (i.e. Tasmania, see Appendix 1), while that of *A. angustior* is "New Holland" (i.e. the Australian mainland), I thought it appropriate to utilise the former name for the species I studied in Tasmania. By adopting this nomenclature it is possible at some later time to recognise that *A. angustior* may be a species unique to the Australian mainland and not *A. obscuricornis* as found in Tasmania.

Under light microscopy the holotype of *A. angustior* appears much lighter than specimens *A. obscuricornis*. As mentioned previously I have observed a great deal of colour variation in the specimens of the latter species collected from Tasmania ranging from pale grey to light brown to almost black. In some instances there appears to be an effect due to age (see comments following *A. obscuricornis*), however, this requires further investigation. Bashford (1992) found that adult insects were light brown in colour following eclosion but became progressively darker with increasing age. Seymour and Bowman (1994) noted that russet body colouration has been used as an indicator of reproductive diapause in adult *Nezara viridula* (L.) (Hemiptera: Pentatomidae). These authors presented evidence to show that this colouration is not always associated with diapausing individuals. It may be possible that such a mechanism is present in adult *Amorbus*. Should *A. obscuricornis* and *A. angustior* be confirmed as being conspecific, it would be interesting to investigate colour differences between specimens from different geographic locations. For example, it could be that *A. obscuricornis* specimens from Tasmania have adapted to the more southerly latitude by becoming darker in colour than their mainland counterparts, in order to better absorb heat from sunlight.

3.4ii. The Genus *Amorbus*.

According to Carver *et al.* (1991) the genus *Amorbus* consists of "about 15 very similar-looking spp." The results of this study (and those of Dr G.F. Gross) suggest that the genus may comprise 20 or more species. Presently, eight named species (*A. alternatus*, *A. atomarius*, *A. biguttatus*, *A. bispinus*, *A. obscuricornis*, *A. rhombifer*, *A. robustus* and *A. rubiginosus*) can be readily identified. Another five named "species" (*A. abdominalis*, *A. angustior*, *A. hirticulus*, *A. rhombeus* and *A. subserratus*) need confirmation through examination of holotypes and/or collection of additional specimens in order to ascertain whether these species are synonyms (*A. angustior* with *A. obscuricornis*; *A. hirticulus* with *A. alternatus*; *A. rhombeus* with *A. rhombifer*) or are indeed unique species (for example *A. abdominalis* and *A. subserratus*, the holotypes of which were both described from specimens collected on Melville Island). In addition, 7 new species have been identified and it is possible that another 2 to 3 exist.

I consider it likely that other new *Amorbus* species exist, both in the field and amongst the existing collections. This is because these insects are often relatively low in abundance and it is probable that current collections do not have representatives of all the species. Additionally, because the known members of the genus appear to posses a high degree of phenotypic variation and sometimes have wide geographic and host ranges, it is

likely that some specimens have been designated a single "species" which may actually be a species complex.

That some *Amorbus* species are very similar in external appearance is also reflected in the comments of Lansbury (1993 *in lit.*) who wrote; "It seems to be a rather difficult genus of two or more species-groups." The *Amorbus* species in Table 3.5 are grouped into 4 species-groups, namely the *A. obscuricornis*-like group, the *A. rhombifer*-like group, the *A. alternatus*-like group and the *A. rubiginosus*-like group. The first two groups are considered more alike than the latter two, primarily because these species lack large, luteous, maculae. Species within the *A. obscuricornis*-like group are considered most similar because they have a similar body shape and the ♂♂ possess triangular keels on the hind femora. The members of the *A. rhombifer*-like group are of a similar body shape typified by the distinctly broadened laterotergites of the abdomen and ♂♂ posses low keels on the hind femora. The characteristic feature of species belonging to the *A. alternatus*-like group is the distinct luteous bands of the connexivum. The species assigned to the *A. rubiginosus*-like group have a similar body shape to *A. rubiginosus*, but lack the banding of the connexivum to assign them to the *A. alternatus*-like group. *A. robustus*, *A. biguttatus* and *Amorbus* n. sp. 5 are considered "unique species" because aspects of their morphology prevent their assignation to one of the species-groups cited. For example, *A. robustus* has the large, luteous, maculae and row of femorial spines as found in members of the *A. alternatus*-like group, but lacks the distinct luteous bands of the connexivum. Similarly, *A. biguttatus* has a triangular keel on the hind femora, as found in the members of the *A. obscuricornis*-like group, but also possesses a row of small femorial spines and is mostly luteous in colour as opposed to brown. Lastly, *Amorbus* n. sp. 5 has a low keel on the hind femora of ♂♂, as is found in ♂♂ of the *A. rhombifer*-like group, but lacks the expanded laterotergites of the abdomen and is luteous in colour as opposed to brown.

Table 3.5. Listing of *Amorbus* species into "species-groups" (see also Table 3.4 and discussion).

A. obscuricornis-like group	*A. rhombifer*-like group	Unique species	*A. alternatus*-like group	*A. rubiginosus*-like group
A. angustior†	*A. rhombeus*†	*A. robustus*	*A. hirticulus*†	*Amorbus* n. sp. 2†
A. bispinus	*Amorbus* n. sp. 1	*A. biguttatus*	*A. atomarius*	*A. subserratus*
Amorbus n. sp. 4	*Amorbus* n. sp. 7	*Amorbus* n. sp. 5	*Amorbus* n.sp. 3*	
Amorbus n. sp. 6				

† maybe conspecific.
* lacks large, luteous, maculae.

As mentioned in Chapter 1, this work is not intended to be a full taxonomic revision of *Amorbus* as this was not originally thought necessary. When it was found that this pre-conception was incorrect, the time required to undertake a full taxonomic revision was deemed to impinge upon the other objectives of the project. It is hoped that this work could be used as a platform for commencing this task.

Chapter 4

Biogeography and Seasonal Phenologies of the Genera *Gelonus*, *Acantholybas* and *Amorbus* in Australia

Chapter 4

Biogeography and Seasonal Phenologies of *Gelonus*, *Acantholybas* and *Amorbus* in Australia

4.1. *Introduction*

4.1i. Ecological Biogeography.

All organisms inhabit specific geographic regions which comprise the species *distribution*, *range* or *area of endemism* (Cranston and Naumann 1991). Relatively few species are widely ecologically tolerant (*eurytopic*), most exist within a limited number of similar habitats which encompass their preferred range of environmental variables, be they abiotic and/or biotic. Climate, in particular temperature and moisture, are generally considered to be the major determinants influencing a species distribution (Davidson 1936; Jeffree and Jeffree 1994).

The biogeography of members of the Hemiptera has received comparatively little attention, with some exceptions (Evans 1959, 1967; Jansson 1980; Duffels 1986; Schuh and Stonedahl 1986; Qin and Gullan 1989; Qin *et al.* 1994). Jansson (1980) postulated that the present day distribution of *Arctocorisa carinata* (C. Sahlberg) (Corixidae) resulted from direct dispersal and that later population isolation was due to climatic and habitat changes. Schuh and Stonedahl (1986) considered the biogeography of mirids, insects closely allied to coreids, but their approach did not consider the influence of the distribution of mirid host plants. The lack of information regarding the ecological biogeography of phytophagous Hemiptera may reflect the lack of knowledge concerning their host plants.

This chapter illustrates the distributions of species belonging to the three coreid genera considered in this thesis and presents data concerning their seasonal phenologies in Australia. The distributions of these insects are related to the known distributions of their *Eucalyptus* host plants. Within Tasmania, the distribution of *A. obscuricornis* and *G. tasmanicus* is considered in detail.

4.1ii. Biogeography and Climate of Australia.

The Australian continent, New Guinea and some adjacent islands have been recognised as regions of high endemism exemplified by, among others, *Eucalyptus* trees, morabine grasshoppers and monotreme mammals (Keast 1959). Spencer (1896) divided Australia

into three regions: the Torresian, Bassian and Eyrean. These regions are still recognised today, however, they are more commonly known as the Tropical, Temperate and Eremaean zones (after Burbidge 1960), respectively.

A number of authors have considered the biogeographic regionalisation of Australia (see Burbidge 1960; Barlow 1985; Thackway and Cresswell 1995). The most recent, namely that by Thackway and Cresswell (1995), recognised 80 Australian biogeographic regions (Fig. 4.1). The factors used to delimit these regions included climate, lithology/geology, landform, vegetation, flora and fauna, land use and other attributes where required. In Tasmania 8 regions were recognised, the attributes of which are detailed beneath Fig. 4.1.

Keast (1959) considered that Australian climatic regions were approximately parallel from north to south and graded into one another at their margins. Many of these regions resemble those discussed in Gentilli (1972). As noted by Davidson (1934), rainfall in much of the tropical north of the country is summer dominant whilst in the more temperate south it is winter dominant. Davidson (1934, 1935, 1936) related temperature and moisture to delimit bioclimatic zones within Australia and related these to the ecology of insects. In particular, the ecological significance of the "precipitation-evaporation" ratio (P/E) to the distributions of Australian insects was emphasised. The P/E ratio is an index of a region's wetness or dryness.

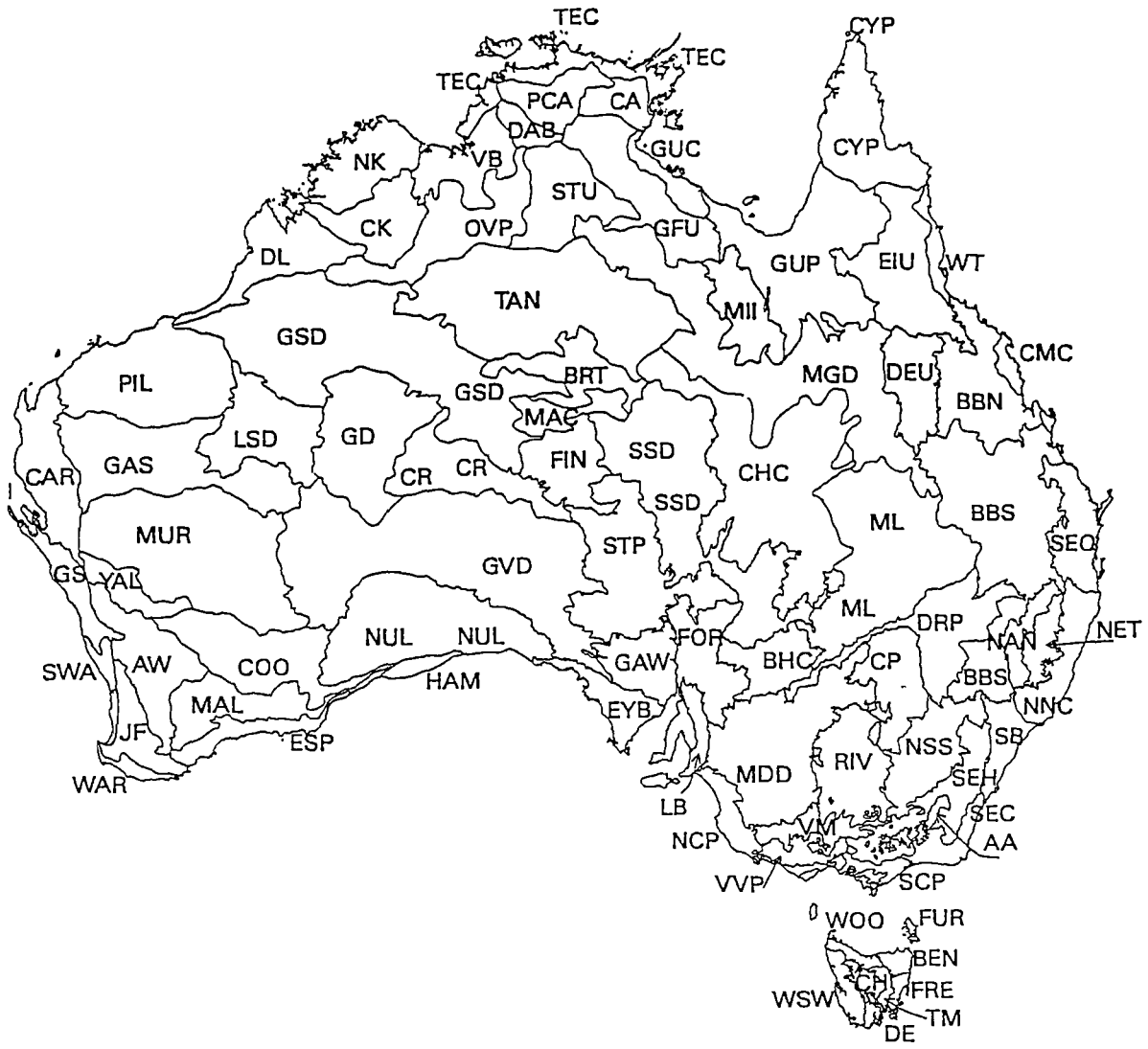
4.1iia. Biogeography and Climate of Tasmania.

Tasmania is an island (with no place more than 115 km from the sea), lying between 40°S and 43.5°S and has a temperate maritime climate (Anonymous 1993). The marine influence on temperature is significant, however, there is a small continental effect evinced by the fact that daily coastal temperatures fluctuate within an approximately 7°C range, in contrast to inland daily temperatures which can be almost double this range. In sharp contrast to Northern Hemisphere conditions at the same latitude, the heat absorption and storage by the oceans surrounding Tasmania produces mild winters and cool summers.

Much of Tasmania is mountainous (highest elevation 1617 m) and it is this factor, together with distance from the coast, which governs the variation in temperature (Anonymous 1993). The prevalence of westerly winds creates a distinct west to east variation in cloudiness and rainfall. During mid September and mid March these gales

attain their greatest strength and persistence creating a clear maximum in the rainfall distribution in the west and northwest. By comparison, the rainfall in the east and southeast is more evenly distributed throughout the year. The present distribution of plant communities found in Tasmania can be seen in Fig. 4.2 (Kirkpatrick and Dickinson 1984). Davidson *et al.* (1981) note that the distributions of Tasmanian eucalypts is broadly determined by climate. It is the temperature and rainfall gradients found within the state that divide the eucalypts into wet, dry and subalpine sclerophyll forests (see Table 4.2). These authors note that these forest types are not discrete entities and often intergrade at their margins. The Tasmanian flora resembles that which was widespread in Australia during the early Tertiary, and perhaps in Gondwanaland prior to its fragmentation (Barlow 1981). Thus, it is characterised by Gondwanan elements, plants with northern hemisphere affinities and autochthonous subflora (Barlow 1981; Martin 1994).

Summers are mild and typified by greatly increased photoperiods, in midsummer there are approximately 15 hours of daylight. In contrast, the daylength in midwinter is about 9 hours (Anonymous 1993). The climatic regions of Tasmania are illustrated in Fig. 4.3.



Figs 4.1. Biogeographic regionalisation of Australia (from Thackway and Cresswell (1995)). The following key relates to Tasmanian regions:

BEN: Ben Lomond. Moist and dry subhumid warm coastal plains..., and humid cool/cold mountain ranges... Lowland vegetation comprising mainly open sclerophyll woodlands and heath while the upper slopes consist of wet sclerophyll forests, some rainforest and alpine vegetation in the highest regions...

CH: Central Highlands. Perhumid cool to cold high plateau..., and humid cool to cold lower plateau... Vegetation ranging from dry sclerophyll woodlands and wet sclerophyll forest on the lower plateau to alpine complexes and coniferous forest patches on the higher plateau...

DE: D'Entrecasteaux. Mainly humid cool mountainous areas with some undulating coastal lowlands. Vegetation heavily forested, grading from mixed forest, wet sclerophyll forest and patches of rainforest in the uplands to dry sclerophyll forest and heath on the coastal lowlands...

FRE: Freycinet. Subhumid cool to subhumid warm coastal plains and low mountain ranges... Vegetation predominantly dry sclerophyll forest, with patches of wet sclerophyll forest, relict rainforest, coastal heath and dry coniferous forest...

FUR: Furneaux. Moist subhumid warm granitic island chain, comprising coastal plains... and low ranges... Vegetation comprising a graduation from heath, scrub and dry woodlands to dry sclerophyll forest with gullies of wet sclerophyll forest and rainforest remnants on the ranges...

TM: Tasmanian Midlands. Dry-moist subhumid cool inland lowland plain... Heavily modified vegetation comprising grasslands and grassy woodlands...

WOO: Woolnorth. Humid warm coastal plains and deeply dissected lowland hills,... Complexes of... sediments covered with wet sclerophyll, dry sclerophyll and coastal heaths with some rainforest, swamp forest and scrub...

WSW: West and South West. Perhumid cold lowlands, low hills and low ranges, comprising a complex mosaic of rainforest, scrub and buttongrass moorlands...

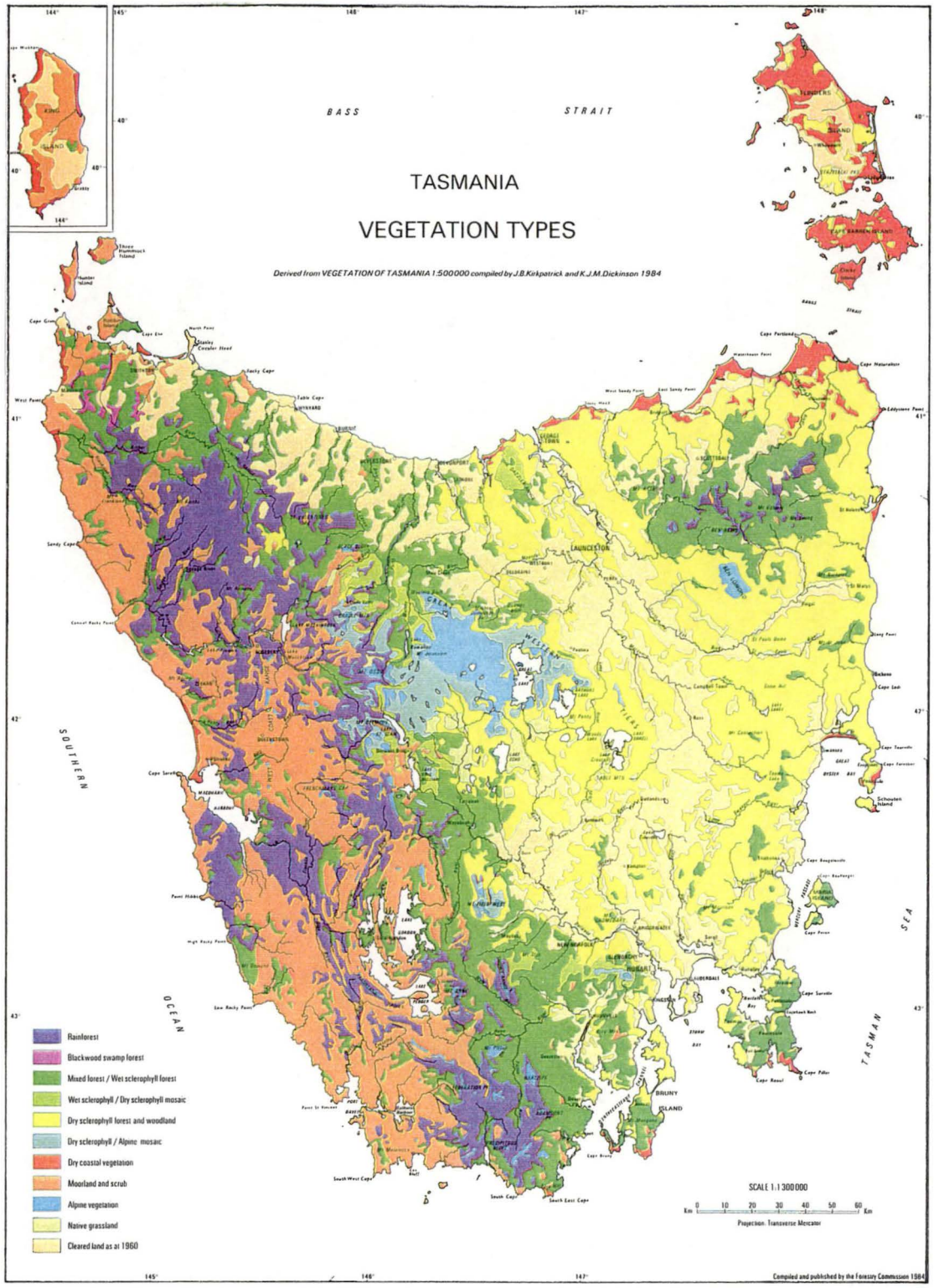


Fig. 4.2. Map of Tasmania illustrating: **(4.2)** the distribution of plant communities (Kirkpatrick and Dickinson 1984). The following definitions of "sclerophyll forest" are of relevance to this figure:

Dry sclerophyll forest is "typified by the presence of a predominantly hard-leafed (xeric) shrub stratum, growing under a eucalypt canopy of varying density (open forest to open woodland) and a mixed (uneven) age structure. Tree age generally correspond to past fire years. The ground layer is variable, however heaths, bracken, grass or sclerophyllous monocotyledons are the most common components." (Duncan 1981)

Wet sclerophyll forest "is essentially two-layered with a tall dominant stratum of eucalypts with a projective cover of about 40% at maturity. A second canopy of tall understorey species is formed at about one-sixth the height of the dominants. The understorey layer has a projective cover of about 90%." (Jackson 1981b)

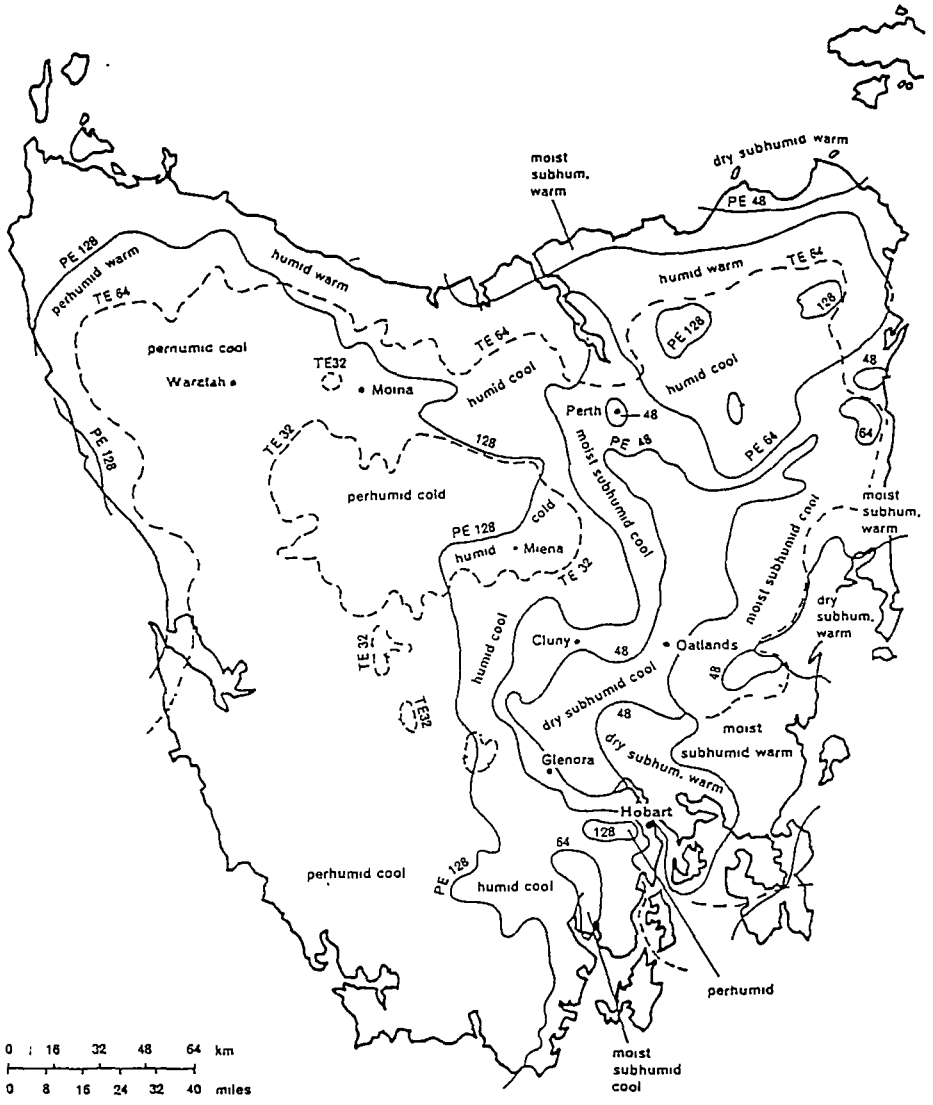


Fig. 4.3. Map of Tasmania illustrating climate (Gentilli 1972). (Precipitation effectiveness (*PE*) limits are shown by solid lines, temperature effectiveness (*TE*) limits by broken lines. *PE* is the summed monthly ratio of precipitation and temperature, whilst, *TE* is the summation of monthly temperatures above freezing.)

4.1iii. Ecological Traits of Eucalypts.

The distribution of a phytophagous organism is intricately associated with that of it's host plant (Evans 1959; Schuh and Stonedahl 1986; Cranston and Naumann 1991). Indeed, it was the recognition of this fact that caused host plant utilisation to be a major topic of investigation for this thesis. Thus, the environmental factors which influence the distribution of eucalypts may play an important role in the biology of coreids which exist upon them. The genus *Eucalyptus* may conceivably have arisen during the Paleocene (Martin 1994) and come to prominence during the Miocene (Wood 1959). Hill (1994) considers that during the mid-Tertiary eucalypts dominated the xeric vegetation of the Australian interior. As the continent became increasingly arid many of these eucalypts were displaced to the coastal margins. The present distribution of the genus *Eucalyptus* can be seen in Fig. 4.4i.

Noble (1989) compared the ecological traits of Australian eucalypt species from the two largest subgenera, *Monocalyptus* and *Symphyomyrtus*, in an attempt to explain possible reasons for the existence of "mixed stands" of these plants. These are the only subgenera of *Eucalyptus* represented in Tasmania. Noble's findings, which he considered should be treated as hypotheses rather than established differences, are presented in Table 4.1.

Table 4.1. Comparison of the ecological traits of the eucalypt subgenera *Eucalyptus* (Monocalyptus) and *Eucalyptus* (Symphyomyrtus) (from Noble 1989).

1. *Monocalyptus* species carry a lower diversity of leaf herbivores and pathogens and suffer less leaf loss and damage by them than *Symphyomyrtus* species. This difference cannot be directly related to leaf nutrients or secondary compounds.
2. *Monocalyptus* species tend to occur on more mesic (i.e. environments with a moderate amount of moisture) sites than *Symphyomyrtus* species. Where they occur on the same sites as *Symphyomyrtus* species, they suffer greater damage during droughts. The precise physiological basis for this difference is not clear.
3. *Monocalyptus* species are less tolerant of flooding.
4. *Monocalyptus* species are less resistant to frost, especially under waterlogged conditions.
5. *Monocalyptus* species are less resistant to saline conditions.
6. *Monocalyptus* species tend to be found on soils of lower nutrient availability than *Symphyomyrtus* species, and they appear to be more dependent on mycorrhizae for vigorous growth, although the relationship is not obligate.
7. *Monocalyptus* species are less resistant to *Phytophthora cinnamomi*. This may be related to differences in the relationship between the eucalypt species and their mycorrhizae.
8. *Monocalyptus* species show slower germination, resprouting and early growth than *Symphyomyrtus* species but appear to catch up relatively quickly.

In addition to temperature, rainfall and soil type, another important environmental factor influencing the distribution of eucalypts is fire (Davidson *et al.* 1981). When fire is common, the eucalypt forest cannot reach maturity and set seed before fire re-occurs. Repeated intense fires at intervals of less than 15 years can kill those eucalypts able to regenerate from epicormic buds and lignotubers leading to replacement by rapidly reproducing heaths, sedges, grasses and ferns. Thus, the distribution of many *Eucalyptus* species are dependent on fire frequency.

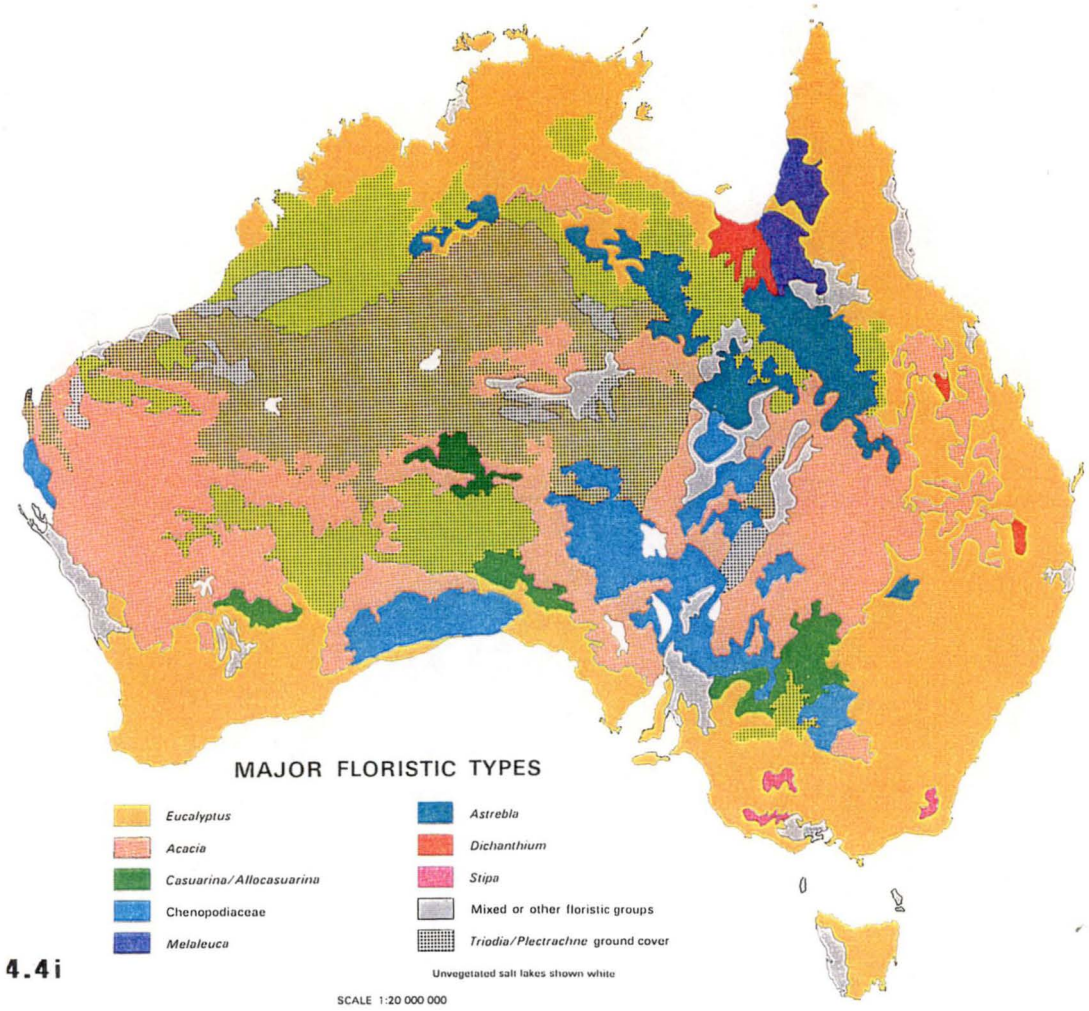
Davidson *et al.* (1981) detailed the "general ecological principles" influencing the distribution of eucalypts within Tasmania (Table 4.2). They considered that where the soil profile is deep, and thus soil moisture is not limiting, and where extremes of temperature do not occur, the forest type is usually wet sclerophyll dominated by eucalypts of the subgenus *Monocalyptus* species, namely the "ashes". Dry sclerophyll forests are dominated by another group of *Monocalyptus* species, the "peppermints". In both wet and dry sclerophyll forests members of the subgenus *Symphyomyrtus* ("gums") may occur as subdominants. Pure stands of *Symphyomyrtus* usually only form in sites where there is a salinity or waterlogging problem. The subalpine forests may be dominated by members of either subgenus depending on the quality of the habitat.

Table 4.2. The preferred habitat of each of the Tasmanian eucalypts (from Davidson *et al.* 1981).

Species	Subgenus/ Series	Preferred habitat
Dry sclerophyll		
E. sieberi	*Mono/Psa*	Dry infertile soils in the north-east
*E. amygdalina**	*Mono/Rad*	Dry sandy podzolic soils, mainly developed on sandstones in the east
*E. pulchella**	*Mono/Rad*	Dry soils developed on dolerite in the south-east
*E. tenuiramis**	*Mono/Rad*	Dry soils developed on mudstone in the south-east
*E. risdonii**	*Mono/Rad*	Very dry shallow soils developed on mudstone in the south-east
E. radiata	*Mono/Rad*	Ordivician gravels in the Forth River gorge
*E. viminalis**	*Symp/Vim*	Coastal and riverine corridoors in dry habitats, often subdominant
E. rubida	*Symp/Vim*	Replaces *E. viminalis* on very dry and cold sites
*E. ovata**	*Symp/Fov*	Normally dry but occasionally waterlogged sites
E. barberi	*Symp/Fov*	Mallee on dry hilltops in the Eastern Tiers
E. perriniana	*Symp/Vim*	Poorly drained, extremely shallow soils in frosty sites
E. morrisbyi	*Symp/Vim*	Local on poor coastal mudstone soils in the south-east
Wet sclerophyll		
*E. regnans**	*Mono/Reg*	Sites with low fire frequency, on moist, deep, well drained soils
*E. obliqua**	*Mono/Euc*	Replaces *E. regnans* on slightly drier sites with a higher fire frequency
*E. globulus**	*Symp/Vim*	Coastal and in well drained valleys
E. cordata	*Symp/Vim*	Local on well drained dolerite soils in the south-east
E. dalrympleana	*Symp/Vim*	Replaces *E. viminalis* in colder, wetter sites
E. brookeriana	*Symp/Fov*	Well drained rocky soils or alluvial deposits adjacent to streams
E. rodwayi	*Symp/Fov*	Replaces *E. ovata* on poorly drained soils at medium altitudes
Subalpine		
*E. delegatensis**	*Mono/Euc*	Replaces *E. obliqua* and *E. regnans* at higher altitudes
*E. coccifera**	*Mono/Rad*	Cold well drained sites, forms treeline in the centre and south-east
*E. nitida**	*Mono/Rad*	Poor quartzite and peat soils in west and south-east
E. pauciflora	*Mono/Euc*	Well drained sites in cold habitats in centre and east
E. vernicosa	*Symp/Vim*	Exposed alpine habitats, quartzite mountains, of the west and south-west
*E. subcrenulata**	*Symp/Vim*	Replaces *E. vernicosa* on less exposed sites
E. johnstonii	*Symp/Vim*	Replaces *E. subcrenulata* toward the south-east
E. urnigera	*Symp/Vim*	Cold sites on well drained dolerite soils
*E. gunnii**	*Symp/Vim*	Cold, waterlogged sites, mainly central
E. archeri	*Symp/Vim*	Upper woodlands, moderate exposure, forms treeline in north-east

* these species are considered further in Chapters 6 and 7.

Key: *Mono* = *Monocalyptus*; *Symp* = *Symphyomyrtus*; *Psa* = *Psathyroxyla*; *Euc* = *Eucalyptus*; *Rad* = *Radiatae*; *Fov* = *Foveolatae*; *Vim* = *Viminales*; *Reg* = *Regnantes* (Series classifications from Chippendale 1988).



4.4i

4.4ii

Figs 4.4i, 4.4ii. (4.4i) the major Australian florisitic types (taken from Anonymous 1990); **(4.4ii)** the states of Australia (key: VIC, Victoria; ACT, Australian Capital Territory; NSW, New South Wales; QLD, Queensland; NT, Northern Territory; WA, Western Australia; SA, South Australia; TAS, Tasmania).

4.1iv. Seasonal Phenology and the Life Cycles of the Coreoidea.

Woodward (1952) classified the life cycle strategies of the Heteroptera into two broad groups which were then subdivided depending upon the degree of inhibition of ovarian development during the least favourable portion of the year. Specifically these groups were:

- species in which oviposition is more or less continuous throughout the year,
- species in which oviposition is restricted to the warmer parts of the year.

Of the Australian coreids only scant information is available concerning their seasonal phenologies. Using collection records, Woodward (1953) proposed that in New Zealand *Acantholybas brunneus* was univoltine with adults of both sexes, and possibly also late instar nymphs, being the overwintering stage(s). Adults were presumed to emerge in spring with oviposition occurring in late spring and early summer. The majority of emerging nymphs completed their development during summer and early autumn. Nymphs emerging from eggs laid comparatively late in the season were considered to form the portion of the population overwintering as late instar nymphs. In notes concerning the biology of *Amorbus alternatus* and *A. rubiginosus*, Kumar (1966) reported finding these insects during December through April in the Brisbane (Qld) area and that stray nymphs were encountered in other months as well. Kumar considered there were probably several generations per year. Green (1972) noted that adults of *Amorbus obscuricornis* and *Gelonus tasmanicus* went into hibernation, apparently amongst litter, during March in southern Tasmania. These adults remained inactive until early October when feeding recommenced. Eggs were thought to be laid during late November, again amongst litter, although this author could not find any eggs *in vivo* (Green 1972). Such observations suggest that these species are univoltine in Tasmania. This assumption is supported by Bashford (1992) who found adult *Amorbus* on eucalypt trees from early October to April with nymphs appearing during November. According to Bashford (1992), *Gelonus* adults were found on trees during late October, however, nymphs were not apparent until early January. Overwintering adults from the previous generation were reported as having mostly disappeared by the end of January (Bashford 1992).

4.2. *Materials and Methods*

4.2i. Biogeography and Adult Abundance of *Gelonus*, *Acantholybas* and *Amorbus*.

Collections of coreid bugs from around Australia were examined and details from specimen labels recorded (Appendix 2). A list of the collections examined can be found in section 3.2vi. Where possible, a grid reference was obtained for each collection locality using the "Master Names File" (MNF) computer database of Australian grid references, compiled by the Australian Surveying & Land Information Group (AUSLIG). Following compilation of these grid references for each of the relevant coreid species, distributions were obtained by plotting these locations using "RangeMapper™ 2.2" [1]. The distributions of eucalypt species recorded on specimen labels as "host plants" were obtained from Chippendale (1988) and Naughton (1995) and are displayed beneath the relevant coreid species distribution.

Adult abundance records for those coreid species not endemic to Tasmania, and of mainland populations of species found in Tasmania, were inferred from specimen labels.

4.2ii. Biogeography and Seasonal Phenology of *Gelonus tasmanicus*, *Acantholybas kirkaldyi* and *Amorbus obscuricornis* in Tasmania.

Detailed Tasmanian distribution maps for each of the three endemic coreid species were prepared using data from pinned specimens and my own field collections. Seasonal phenology data for *A. obscuricornis* and *G. tasmanicus*, collected during field sampling, was summed according to month in order to account for fluctuations in weekly records. Details concerning sampling technique are presented in Chapter 2. Data concerning numbers of coreid nymphs at various stages of development was converted to percentages of a total sample for presentation.

[1] RangeMapper™ 2.2 is a mapping program by Kenelm W. Philip of Tundra Vole Software, Fairbanks, Alaska.

4.3. *Results*

4.3i. Biogeography and Seasonal Phenology of *Gelonus*, *Acantholybas* and *Amorbus*.

Some 1835 coreid specimens from 22 collections were examined. The distributions of *G. tasmanicus*, *A. kirkaldyi* and *A. obscuricornis* and their host plants are presented in Figures 4.5, 4.6. and 4.8, respectively. Details concerning the distributions and host plants of the other coreid species studied are presented in Table 4.3. Distribution maps of these species, and those of associated host plants, are presented in Appendix 3.

• *Gelonus tasmanicus* (Fig. 4.5). On the Australian mainland the species appears restricted to the high altitude regions of the Great Dividing Range and Snowy Mountains. In the main, the distributions of the eucalypt species associated with collections of this species (Figs 4.5a-4.5h) show a high degree of correlation with the distribution of *G. tasmanicus*, except for those eucalypts whose distributions extend into South Australia, i.e. *E. obliqua*, *E. pauciflora* subsp. *pauciflora* and *E. viminalis* subsp. *viminalis*.

• *Acantholybas kirkaldyi* (Fig. 4.6). The re-discovery of *A. kirkaldyi* from Tasmania has confirmed the original type locality as given by Bergroth (1909). The only eucalypt which has been associated with collections of this species is *E. obliqua*. Whether *E. obliqua* is a host plant of *A. kirkaldyi* remains to be determined, however, if it were it remains to be seen whether this species is also found on the Australian mainland in localities inhabited by *E. obliqua*.

Figure 4.7 illustrates the distribution of the genus *Amorbus*. As can be seen from this figure a large number of these records are from sites in New South Wales and to a lesser extent southern Queensland. Not surprisingly the greatest density of records come from regions close to major capital cities, for example Sydney (N.S.W.), Brisbane (Qld), Perth (W.A.) and Hobart (Tas.). In addition, the majority of these records come from either high altitude and/or coastal locations as opposed to more arid inland areas and possibly represents a strong sampling bias.

• *Amorbus obscuricornis* (Fig. 4.8). This species has a distribution which encompasses Tasmania, Victoria, the Australian Capital Territory, New South Wales and southern Queensland, with one record also from Adelaide (South Australia). This South Australian record was from *E. globulus* which is not endemic to the state. In the main the distribution of this species resembles that of *G. tasmanicus*. In total, specimen collection details make reference to some 15 eucalypt species. There is good agreement between the

known distributions of these eucalypt species and that of *A. obscuricornis*.

The results presented in Table 4.4 and Figs 4.9 to 4.19 summarise the information gathered from details concerning collection date on specimen labels. If it is assumed that the period during which adult insects were available for collection corresponds to their active seasonal phase, then it might be further assumed that these collection data are a reasonable reflection of a species seasonal phenology. The conclusions that can be inferred from such records are, however, significantly influenced by the number of specimens examined and the representation from each state. Where collections contained numerous specimens of a particular species (for example, *A. rubiginosus*, *A. obscuricornis* and *G. tasmanicus*) and/or reasonable numbers of specimens from one or two states (for example, *A. alternatus*, *A. rhombifer*, *A. robustus*) the inferences drawn are more likely to be accurate than those based on a few collection records.

The majority of adult coreid specimens have been collected from early spring through to early/mid autumn (Table 4.4), however, some specimens were also collected during late autumn (for example, *A. alternatus* (Qld), *A. biguttatus* (Qld), *A. robustus* (N.T.), *A. rubiginosus* (N.T. and W.A.) and *Amorbus* n. sp. 6 (A.C.T.)) while others were collected during mid/late winter (for example, *A. alternatus* (N.S.W. and W.A.), *A. atomarius* (Qld), *A. rhombifer* (Qld), *A. robustus* (Qld and W.A.) and *A. rubiginosus* (Qld)). As expected, the states and territories in which collection data has the widest temporal distribution are generally more northerly and thus warmer, for example Queensland, the Northern Territory and Western Australia (for location of these states see Fig. 4.4ii). Of the 13 *Amorbus* species considered in Table 4.4 (excluding nymphs), 7 species exhibited their most extended period of activity in Queensland (with *A. rubiginosus* having an equally long period of activity in the Northern Territory). Of the other species, *A. bispinus* is only found in Western Australia, whilst *A. obscuricornis* exhibited it's most extended period of adult activity in New South Wales and *Amorbus* n. sp. 6 in the Australian Capital Territory. *G. tasmanicus* had the longest period of adult activity in Victoria.

That many coreid species only found on the Australian mainland are better adapted to warmer climates can also be inferred from Table 4.4. For example, the period of adult availability for *A. rubiginosus* generally increases as the species distribution extends north-ward, e.g. period of collection in S.A. < Vic. < A.C.T. < N.S.W < Qld = N.T. = W.A. (although S.A. extends further north than Vic. the arid nature of this state

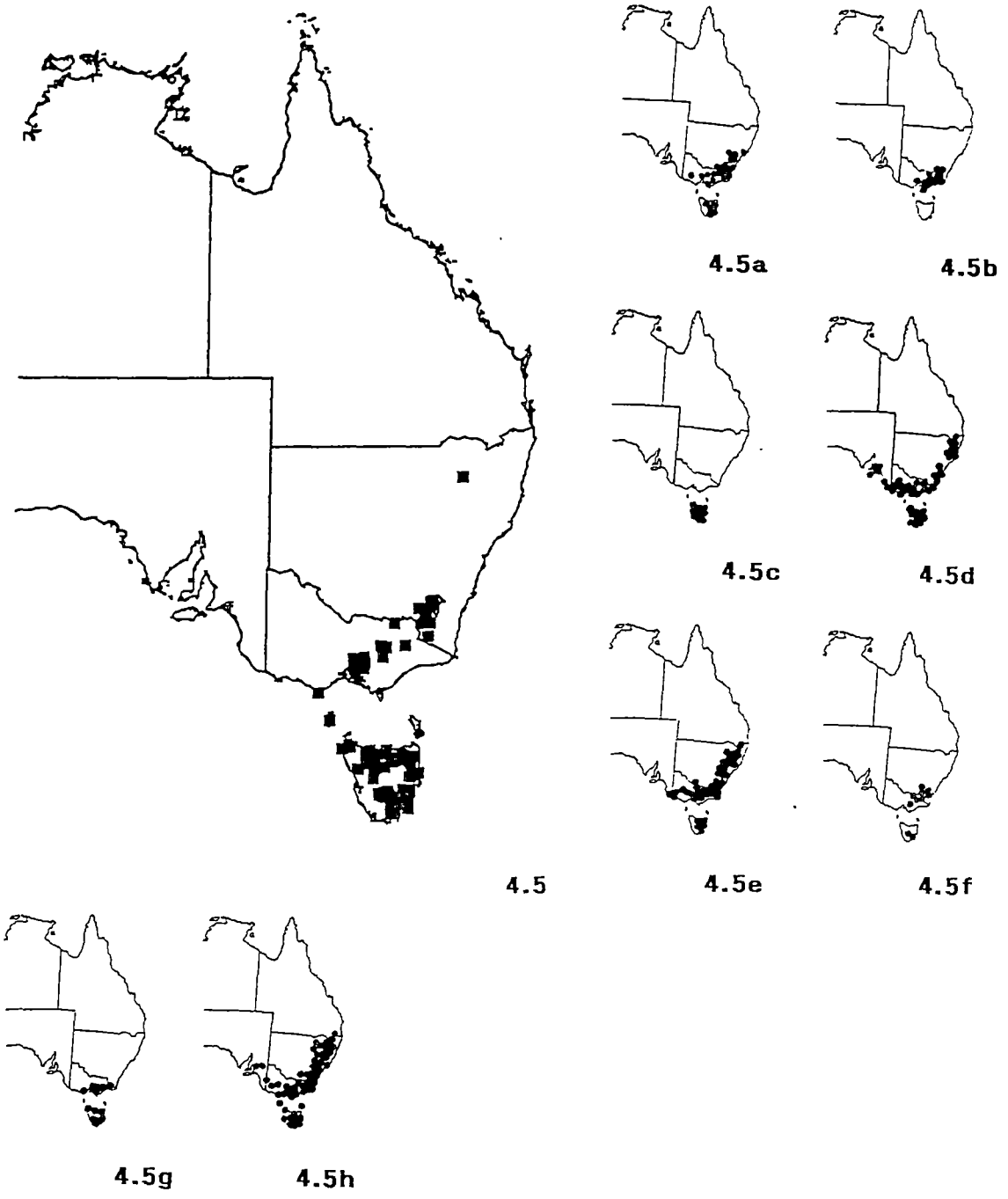
may significantly influence bug activity). Similarly, for *Amorbus* n. sp. 3 where seasonal availability increases thus: Vic. < A.C.T. = N.S.W. < Qld. Conversely, those species which are found in Tasmania, as well as the Australian mainland, generally have shorter periods of adult availability the further north their distributions extend. For example, for *A. obscuricornis* Vic. < A.C.T. < N.S.W. > Qld (where the period of activity in Qld < Vic.). Perhaps the best example of this trend is for *G. tasmanicus* where: N.S.W. < A.C.T. = Vic. This data would suggest that these species are better adapted to cooler climates.

These inferences are generally supported by Figs 4.9 to 4.19. For example, the largest number of specimens of *G. tasmanicus* (Fig. 4.9) and *A. obscuricornis* (Fig. 4.14) examined were collected during November. In contrast, the largest number of collection records for *A. rhombifer* (Fig. 4.15), *A. robustus* (Fig. 4.16) and *A. rubiginosus* (Fig. 4.17) were for dates during March in the case of the first two species and January for the latter. Of the available nymphal *Amorbus* (Fig. 4.10) specimens the greatest number of these had been collected during January.

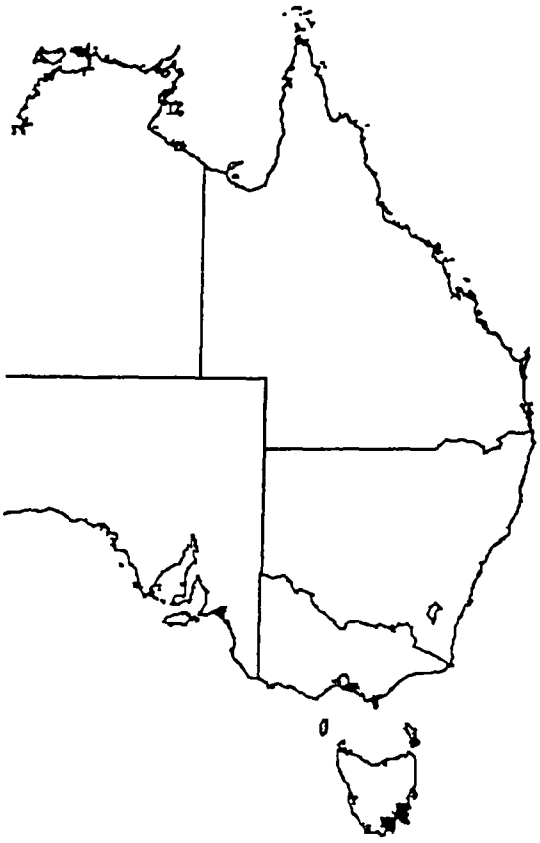
In Tasmania, *A. obscuricornis* disappears during late autumn and winter. This period presumably corresponds with the onset of diapause (see Chapter 5) during which the adults overwinter away from their hosts. Such behaviour is clearly apparent from the restricted period of activity in Fig. 4.14. That species such as *A. alternatus*, *A. rhombifer* and *A. robustus* have been collected during almost all months of the year suggests that activity, in particular diapause activity, may differ considerably between species such as *A. obscuricornis* and *A. alternatus*, *A. rhombifer* and *A. robustus*.

Table 4.3. Distributions and host plant records for species of *Gelonus*, *Acantholybas* and *Amorbus*. (N.B. distribution maps for species other than *G. tasmanicus*, *A. kirkaldyi* and *A. obscuricornis* are presented in Appendix 3.)

Species	Distribution	Host plants –
Gelonus tasmanicus	Tas., Vic. and N S W.	*Eucalyptus dalrympleana* subsp. *dalrympleana*, *E delegatensis* subsp *delegatensis*, *E delegatensis* subsp. *tasmaniensis*, *E. obliqua*, *E. pauciflora* subsp. *pauciflora*, *E perriniana*, *E regnans* and *E viminalis* subsp. *viminalis* (Also recorded on "snow gums" in N S W and "*E. gigantea*" in Tas , a synonym for *E globulus* subsp. *globulus*.)
Acantholybas brunneus	N S W. and Qld	Recorded on Gramineae in N S.W.
A. kirkaldyi	Tas.	*E obliqua*.
A. longulus	Lombok Island, Indonesia	-
Amorbus alternatus	W.A , N.T., Qld, S A., N.S.W. and Vic.	*E. acmenioides* (Kumar 1966), *E blakelyi* and *E drepanophylla* (Kumar 1966)
A angustior	Australia (type locality)	-
A. atomarius	A.C T , N.S.W and Qld	"*Eucalyptus* sp."
A. biguttatus	Qld	-
A bispinus	W A	*E. marginata*.
A obscuricornis	Tas., Vic., S.A., A.C T , N S W. and Qld	*E amygdalina*, *E. dalrympleana* subsp *dalrympleana*, *E delegatensis* subsp. *delegatensis*, *E. dives*, *E fastigata*, *E macrorhyncha* subsp *macrorhyncha*, *E maculata*, *E. ovata*, *E pauciflora* subsp. *pauciflora*, *E. perriniana*, *E pulchella*, *E risdonii*, *E. rossii*, *E stellulata* and *E viminalis* subsp *viminalis* (Also recorded on "*Angophora* sp." in N.S W. and cultivated *E. globulus* in S A)
A rhombifer	Qld, N.S W., W.A. and Vic.	*Angophora subvelutina*, *Eucalyptus amplifolia* and *E. microcorys* (Kumar 1966).
A. robustus	W A., N.T., Qld, and N.S.W	*E. albens*, *E. crebra*, *E. melliodora* and *E microtheca*. (Also recorded on "ironbark" (a *Eucalyptus* sp belonging to the series Siderophloiae) in Qld)
A rubiginosus	W.A , N.T., Qld, N S W., A C.T., Vic. and S A.	*Angophora hispida*, *Eucalyptus acmenioides* (Kumar 1966), *E. blakelyi*, *E bridgesiana*, *E. camaldulensis*, *E cinerea*, *E dives*, *E. fastigata*, *E ganophylla*, *E globulus* subsp *bicostata*, *E. leucoxylon* subsp *leucoxylon*, *E macrorhyncha* subsp. *macrorhyncha*, *E maculata*, *E melliodora*, *E. mucrocarpa*, *E. pilularis*, *E sideroxylon* subsp *sideroxylon*. (Also recorded on plantation *E globulus* subsp. *globulus* in N S W., "*E retragona*" in W A. and "mallee" in W.A)
Amorbus n. sp 1	Qld	-
Amorbus n sp. 3	Vic., A.C.T., N.S.W and Qld	*E. blakelyi*, *E dives* and *E. saligna*. (Also recorded on "*E vemin*" in the A.C.T)
Amorbus n sp. 4	N S.W , S.A. and W A	Recorded on "flowering mallee"
Amorbus n. sp. 5	Qld, N.T. and W A	-
Amorbus n sp. 6	A.C T , N.S W. and Qld	*E. globoidea* and *E macrorhyncha* subsp *macrorhyncha*
Amorbus n sp 7	Banks and Horn Islands , Torres Strait	-

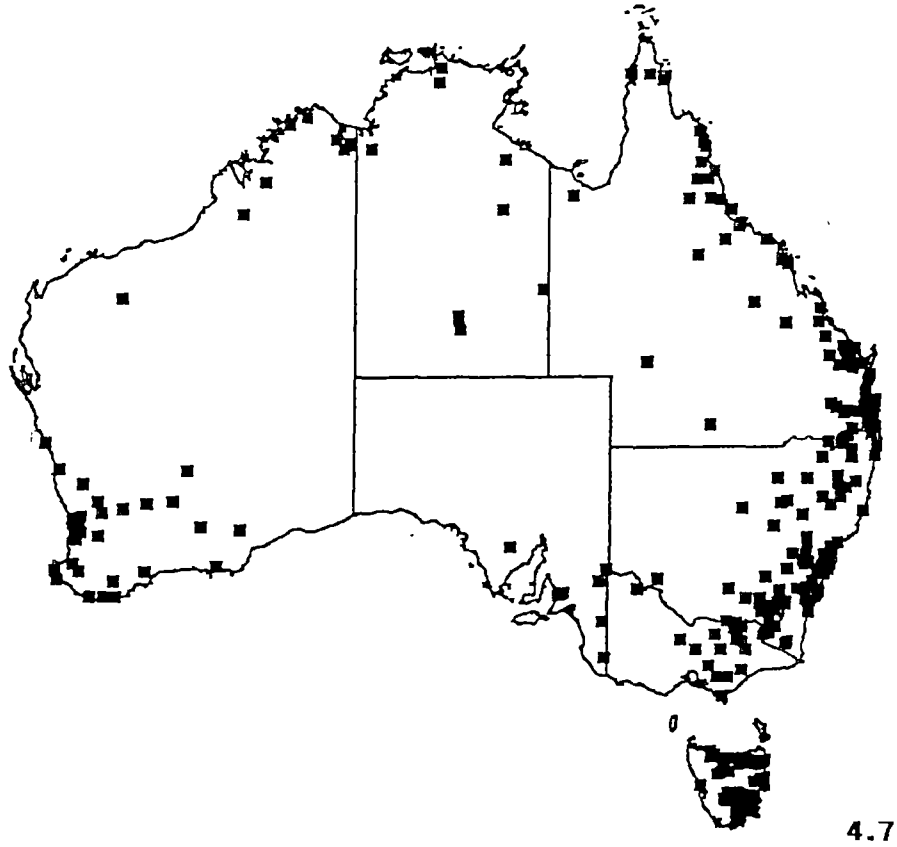


Figs 4.5, 4.5a-4.5h. Distribution maps of: (4.5) *G. tasmanicus* adults and nymphs; (4.5a) *E. dalrympleana* subsp. *dalrympleana*; (4.5b) *E. delegatensis* subsp. *delegatensis*; (4.5c) *E. delegatensis* subsp. *tasmaniensis*; (4.5d) *E. obliqua*; (4.5e) *E. pauciflora* subsp. *pauciflora*; (4.5f) *E. perriniana*; (4.5g) *E. regnans*; (4.5h) *E. viminalis* subsp. *viminalis*. (Also recorded on "snow gums" in New South Wales and "*E. gigantea*" in Tasmania, a synonym for *E. globulus* subsp. *globulus*.)



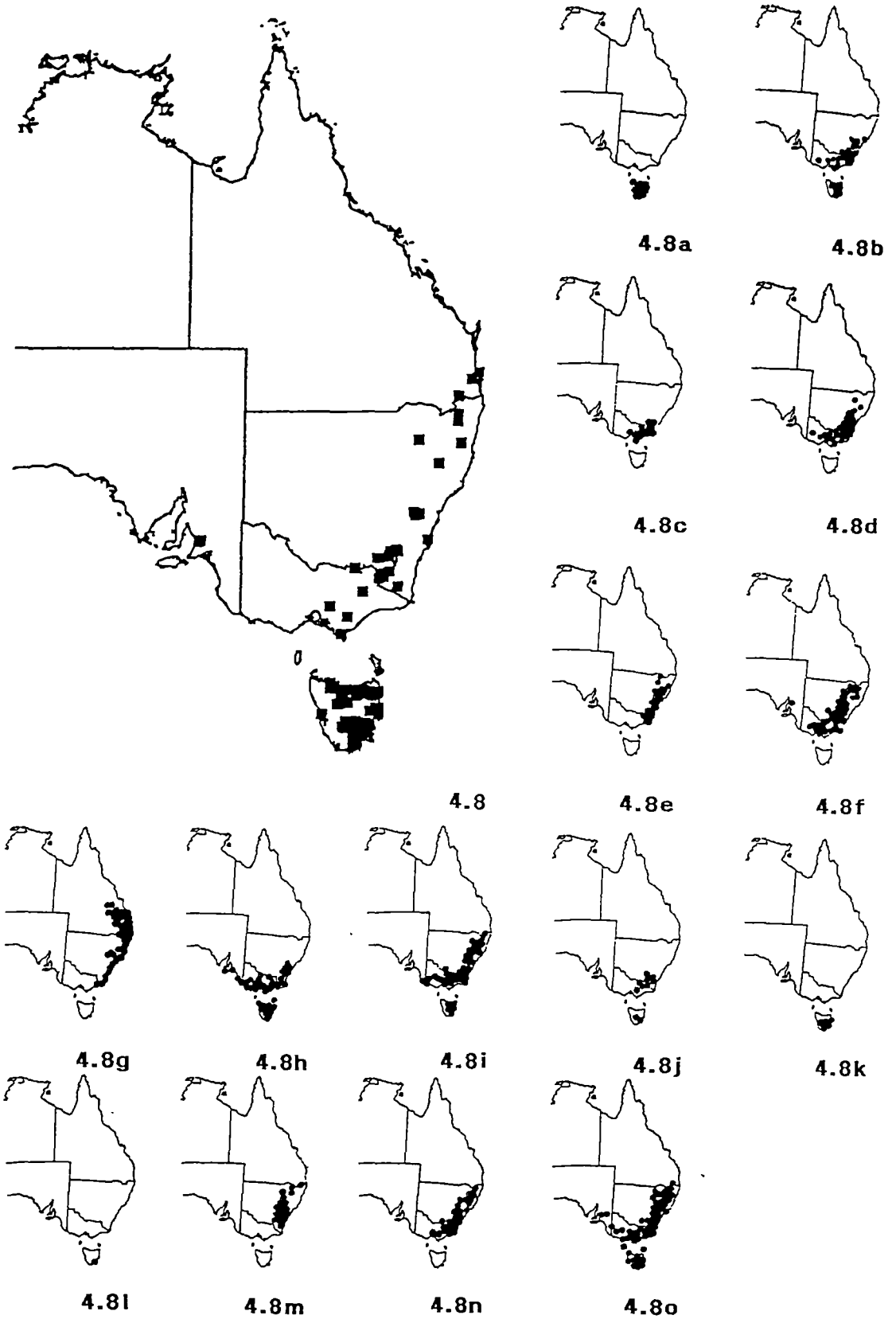
4.6a

4.6



4.7

Figs 4.6, 4.6a, 4.7. Distribution maps of: (4.6) *Acanthotybas kirkaldyi* adults; (4.6a) *E. obliqua*; (4.7) all *Amorbus* spp. adults and nymphs.

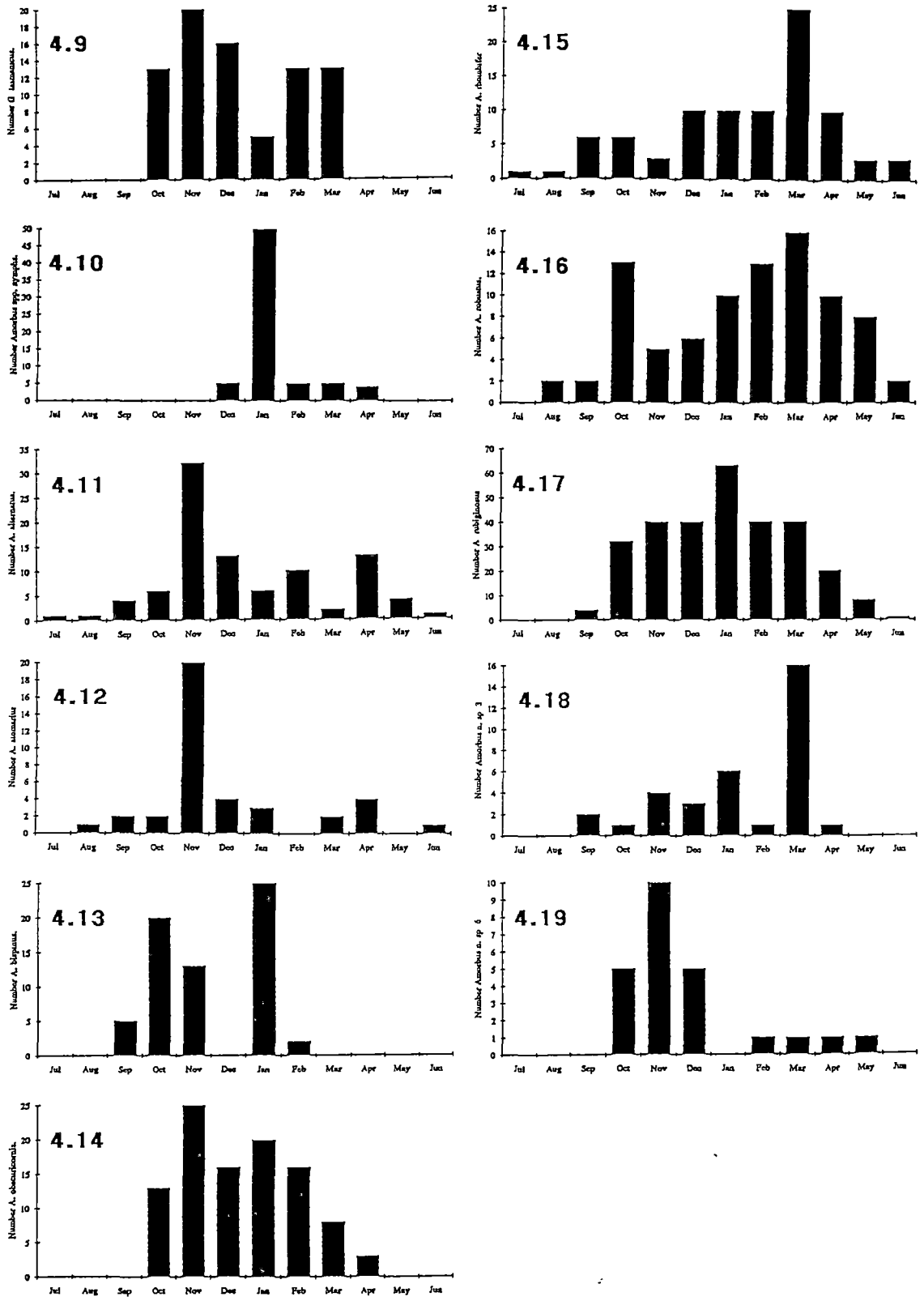


Figs 4.8, 4.8a-4.8o. Distribution maps of: (4.8) *A. obscuricornis* adults and nymphs (latter using Tasmanian records only); (4.8a) *E. amygdalina*; (4.8b) *E. dalrympleana* subsp. *dalrympleana*; (4.8c) *E. delegatensis* subsp. *delegatensis*; (4.8d) *E. dives*; (4.8e) *E. fastigata*; (4.8f) *E. macrorhyncha* subsp. *macrorhyncha*; (4.8g) *E. maculata*; (4.8h) *E. ovata*; (4.8i) *E. pauciflora* subsp. *pauciflora*; (4.8j) *E. perriniana*; (4.8k) *E. pulchella*; (4.8l) *E. risdonii*; (4.8m) *E. rossii*; (4.8n) *E. stellulata*; (4.8o) *E. viminalis* subsp. *viminalis*. (Also recorded on "*Angophora* sp." in New South Wales and cultivated *E. globulus* in South Australia.)

Table 4.4. Earliest and latest (respectively) collection date for adults (unless otherwise stated) of each coreid species from each mainland Australian state. (Records are derived from all the specimens comprising the invertebrate collections examined, see Materials and Methods.) N.B. Where a species' distribution is considered to include a particular state but collection records were not available this is signified by "n/a". Conversely, where there are no species distribution records for a given state, and evidence suggests that the species does not occur in that state, this is signified by a "-". Figures in parentheses represent number of unique specimen collection dates summarised. Species with a single collection date or month record represent sole detail records.

Species	Victoria	Australian Capital Territory	New South Wales	Queensland	Northern Territory	Western Australia	South Australia
G. tasmanicus nymphs (3)	-	-	summer/3 Mar	-	-	-	-
G. tasmanicus (65)	1 Oct/22 Mar	11 Oct/28 Mar	28 Nov/14 Mar	-	-	-	-
A. brunneus (1)	-	-	29 Mar	n/a	-	-	-
Amorbus spp. nymphs (42)	n/a	25 Jan/15 Mar	8 Jan/1 Apr	n/a	n/a	Nov/5 Apr	Feb.
A. alternatus (78)	Jan/Feb	-	4 Nov/21 Jul	16 Aug/31 May	5 Oct/6 Dec	13 Jan/Jun	8 Nov/1 Feb
A. atomarius (19)	-	Apr	28 Oct/13 Dec	27 Sep/10 Aug	-	-	-
A. biguttatus (3)	-	-	-	20 Dec/May	-	-	-
A. bispinus (22)	-	-	-	-	-	26 Sep/13 Feb	-
A. obscuricornis (64)	25 Dec/30 Mar	3 Oct/21 Mar	13 Oct/1 Apr	20 Dec/18 Feb	-	-	17 Oct
A. rhombifer (73)	-	-	15 Sep/15 Mar	26 Sep/30 Jun	-	-	-
A. robustus (74)	-	-	9 Oct/23 Apr	Aug/9 Jun	15 Oct/28 May	19 Dec/11 Aug	-
A. rubiginosus (185)	28 Oct/14 Mar	22 Oct/3 Apr	Sep/3 Apr	14 Oct/10 Jun	23 Sep/31 May	Sep/17 May	8 Nov/10 Feb
Amorbus n. sp. 1 (2)	-	-	-	n/a	-	-	-
Amorbus n. sp. 3 (25)	1 Dec/26 Mar	30 Nov/5 Apr	Oct/14 Mar	15 Sep/27 Mar	-	-	-
Amorbus n. sp. 4 (5)	-	-	24 Oct	-	-	13 Oct/22 Dec	17 Dec/2 Dec
Amorbus n. sp. 5 (4)	-	-	-	25 Nov	22 Jan	25 Jan/10 Mar	-
Amorbus n. sp. 6 (12)	-	23 Oct/30 May	9 Dec/12 Mar	20 Apr	-	-	-

N.B. *A. kirkaldyi* only reported from Tasmania; *A. longulus* occurs on Lombok Island; *A. robustus* and *A. rhombifer* occur in Papua New Guinea; *Amorbus* n. sp. 7 recorded from the Torres Strait.



Figs 4.9-4.19. Number of specimens of various coreid species collected per month on the Australian mainland: (4.9) *G. tasmanicus* adults; (4.10) *Amorbus* spp. nymphs; (4.11) *A. alternatus* adults; (4.12) *A. atomarius* adults; (4.13) *A. bispinus* adults; (4.14) *A. obscuricornis* adults; (4.15) *A. rhombifer* adults; (4.16) *A. robustus* adults; (4.17) *A. rubiginosus* adults; (4.18) *Amorbus* n. sp. 3 adults; (4.19) *Amorbus* n. sp. 6 adults.

4.3ii. Biogeography and Seasonal Phenology of *Gelonus tasmanicus*, *Acantholybas kirkaldyi* and *Amorbus obscuricornis* in Tasmania.

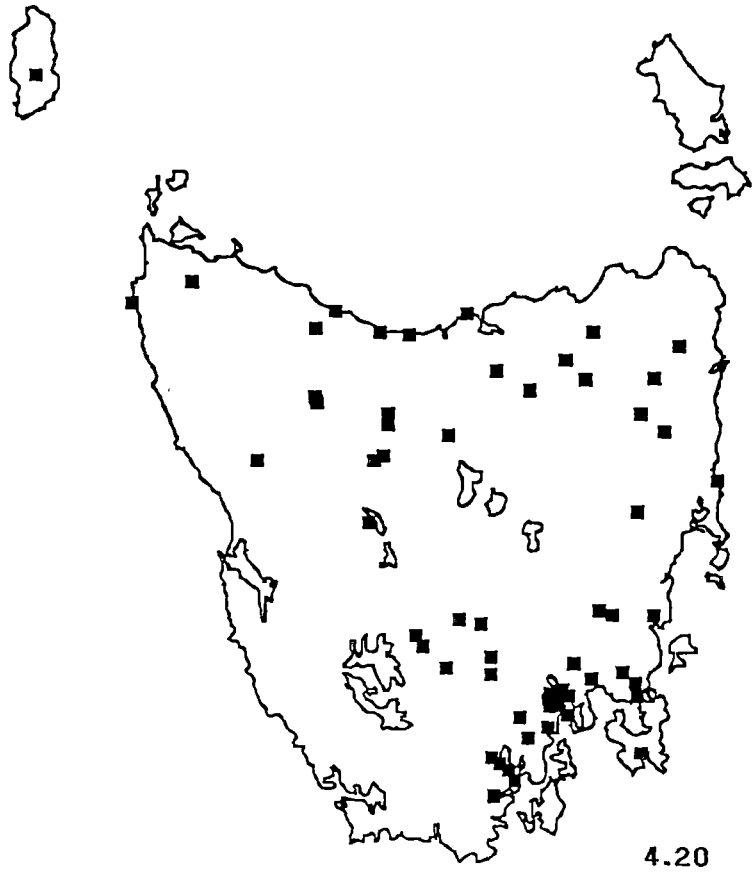
The Tasmanian distributions of *G. tasmanicus*, *A. kirkaldyi* and *A. obscuricornis* are shown in Figs 4.20, 4.21 and 4.22, respectively. The distributions of both *G. tasmanicus* and *A. obscuricornis* exhibit much similarity, including a lack of collection records from the western portion of the state. This is especially noticeable in the case of *A. obscuricornis*, despite one record from Strahan (central west-coast). The records for *G. tasmanicus* extend further into north-west Tasmania than those for *A. obscuricornis*. There has only been one coreid specimen collected from the Bass Strait islands, namely *G. tasmanicus* from King Island. It is possible that the lack of records from the islands in the Bass Strait and the western portion of the state may simply reflect the low human population densities in these regions. Little interpretation of the possible factors influencing the distribution of *A. kirkaldyi* can be made given the paucity of available collection records.

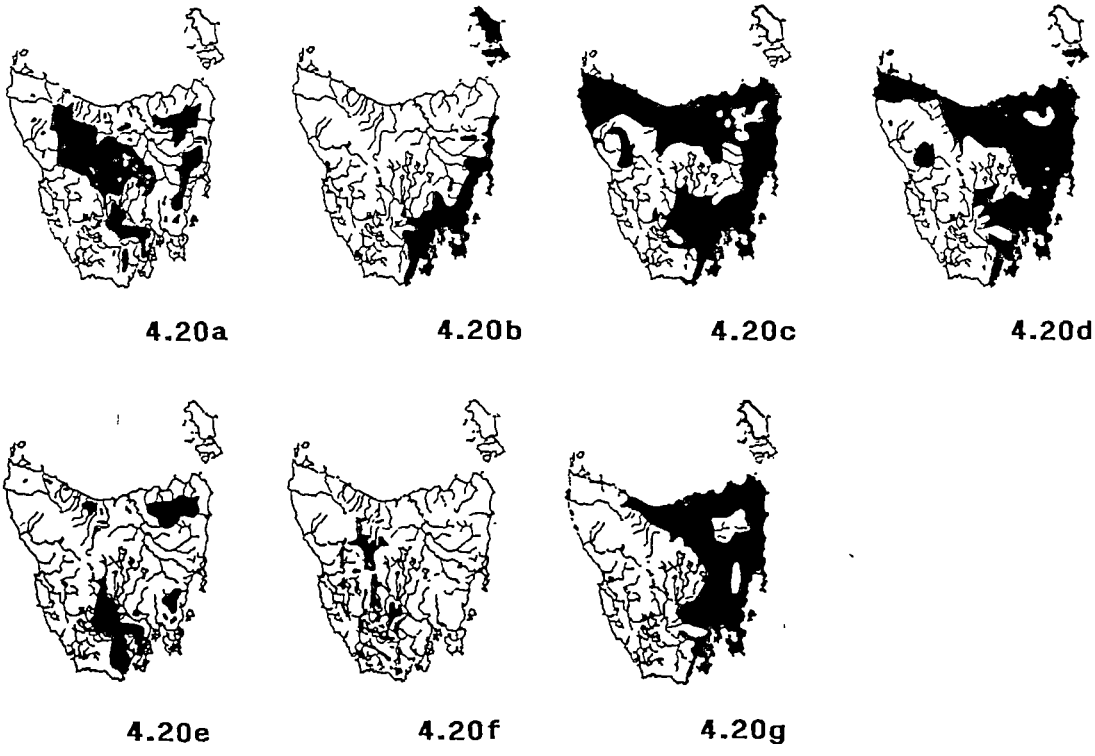
Both *G. tasmanicus* and *A. obscuricornis* exhibit very similar seasonal phenologies in Tasmania. Adults are first seen during early spring (Figs 4.23 and 4.24). Only adult coreids can be found in the field until about late spring (November)/early summer (December) when the first nymphs appear. Nymphs of both species can still be found in the field until about mid autumn (April), while adults remain in the field until about the end of autumn (May). These observations are in good agreement with the findings of Green (1972) and Bashford (1992). Similar information concerning the seasonal phenology of *A. kirkaldyi* is not available as only two specimens of this species were ever found. A male specimen of *A. kirkaldyi* was found on the 7 September 1993 (early spring), whilst, a female specimen was found on the 2 December 1994 (early summer). This suggests that adults of this species are active during spring and summer.

Figures 4.25 and 4.26 summarise the changes in age structure of populations of nymphs of *G. tasmanicus* and *A. obscuricornis*, respectively. Although seasonal phenological studies began in March 1992, it was not until October 1992 that assignation of coreid nymphs to given stadia was possible with absolute certainty. It is for this reason that these data do not match the durations presented in Figs 4.23 and 4.24. The data pertaining to the spring of 1993 and summer of 1993/94 is the most complete and thus the following comments pertain particularly to these data. For both species, all nymphs found during late spring (November) were second instars. By April (mid autumn) all nymphs are fifth instars and approaching eclosion. Again, both species exhibit similar

rates of nymphal development in the field.

Unfortunately, only in one instance (i.e. 28 January 1993) was a small group of three first instar *G. tasmanicus* observed in the field, whilst, in the case of *A. obscuricornis* only one first instar nymph was recorded (28 February 1995, see results from plant architecture experiment in Chapter 7). Similarly, no eggs of either species were collected by me from the field. Thus, it can only be assumed that the first eggs of both species are laid around early to mid spring (September/October) and that first instar nymphs from these eggs appear during mid to late spring (October/November).



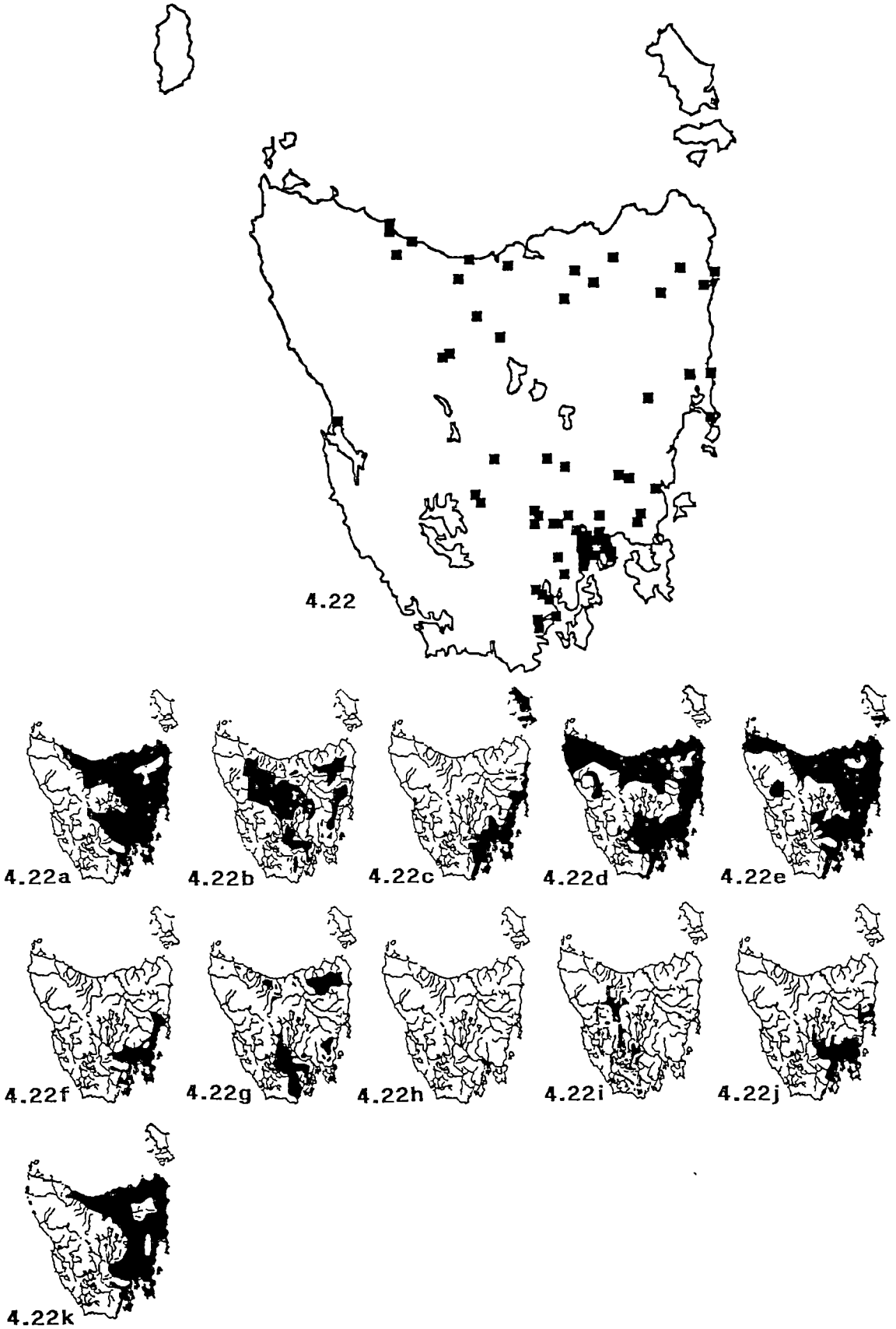


Figs 4.20, 4.20a-4.20g. Distribution maps of: (4.20) *G. tasmanicus* adults and nymphs; (4.20a) *E. delegatensis* subsp. *tasmaniensis*; (4.20b) *E. globulus* subsp. *globulus*; (4.20c) *E. obliqua*; (4.20d) *E. ovata*; (4.20e) *E. regnans*; (4.20f) *E. subcrenulata*; (4.20g) *E. viminalis* subsp. *viminalis*. (Also collected from the introduced plantation species *E. nitens* (juvenile foliage).)

4.21

4.21a

Figs 4.21, 4.21a. Distribution maps of: (4.21) *A. kirkaldyi* adults; (4.21a) *E. obliqua*.



Figs 4.22, 4.22a-4.22k. Distribution maps of: (4.22) *A. obscuricornis* adults and nymphs; (4.22a) *E. amygdalina*; (4.22b) *E. delegatensis* subsp. *tasmaniensis*; (4.22c) *E. globulus* subsp. *globulus*; (4.22d) *E. obliqua*; (4.22e) *E. ovata*; (4.22f) *E. pulchella*; (4.22g) *E. regnans*; (4.22h) *E. risdonii*; (4.22i) *E. subcrenulata*; (4.22j) *E. tenuiramis*; (4.22k) *E. viminalis* subsp. *viminalis*. (Also collected from the introduced plantation species *E. nitens* (juvenile foliage).)

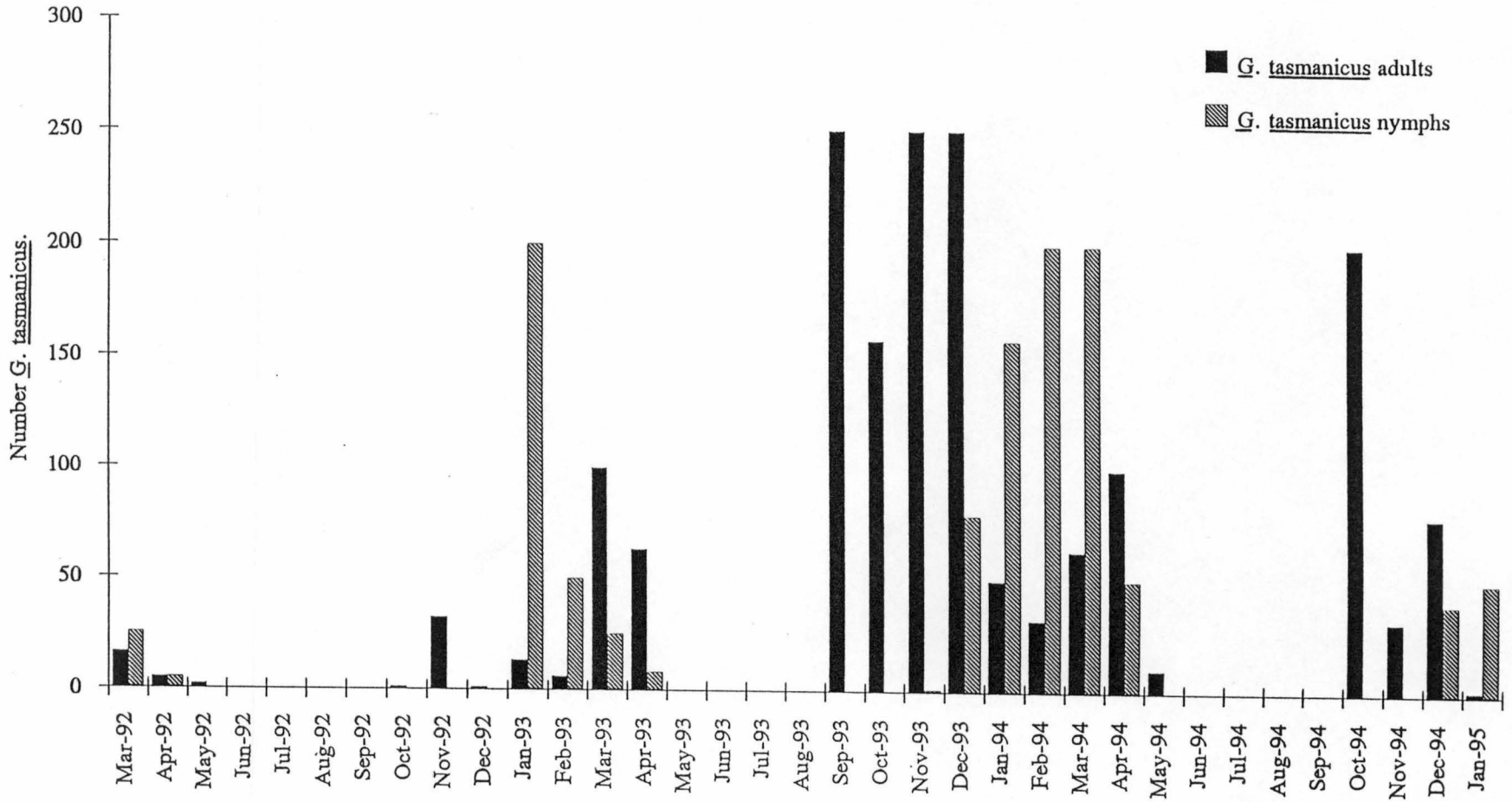


Fig. 4.23. The seasonal phenology of adults and nymphs of *G. tasmanicus* in southern Tasmania from March 1992 to January 1995.

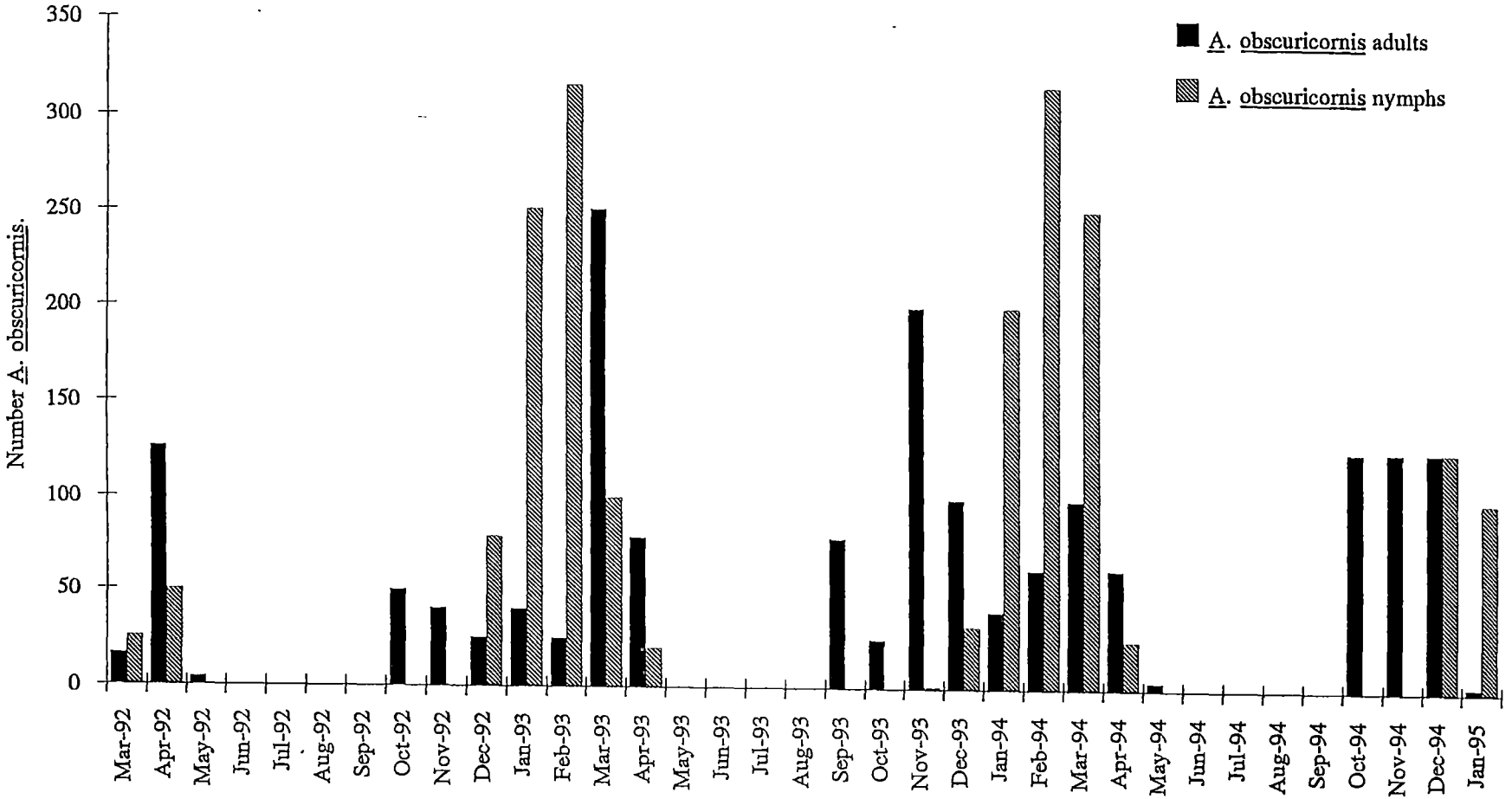


Fig. 4.24. The seasonal phenology of adults and nymphs of *A. obscuricornis* in southern Tasmania from March 1992 to January 1995. (N.B. Similar numbers of adults and nymphs were coincidentally recorded during October to December 1994, thus, the data presented for this period is not a sampling artifact.)

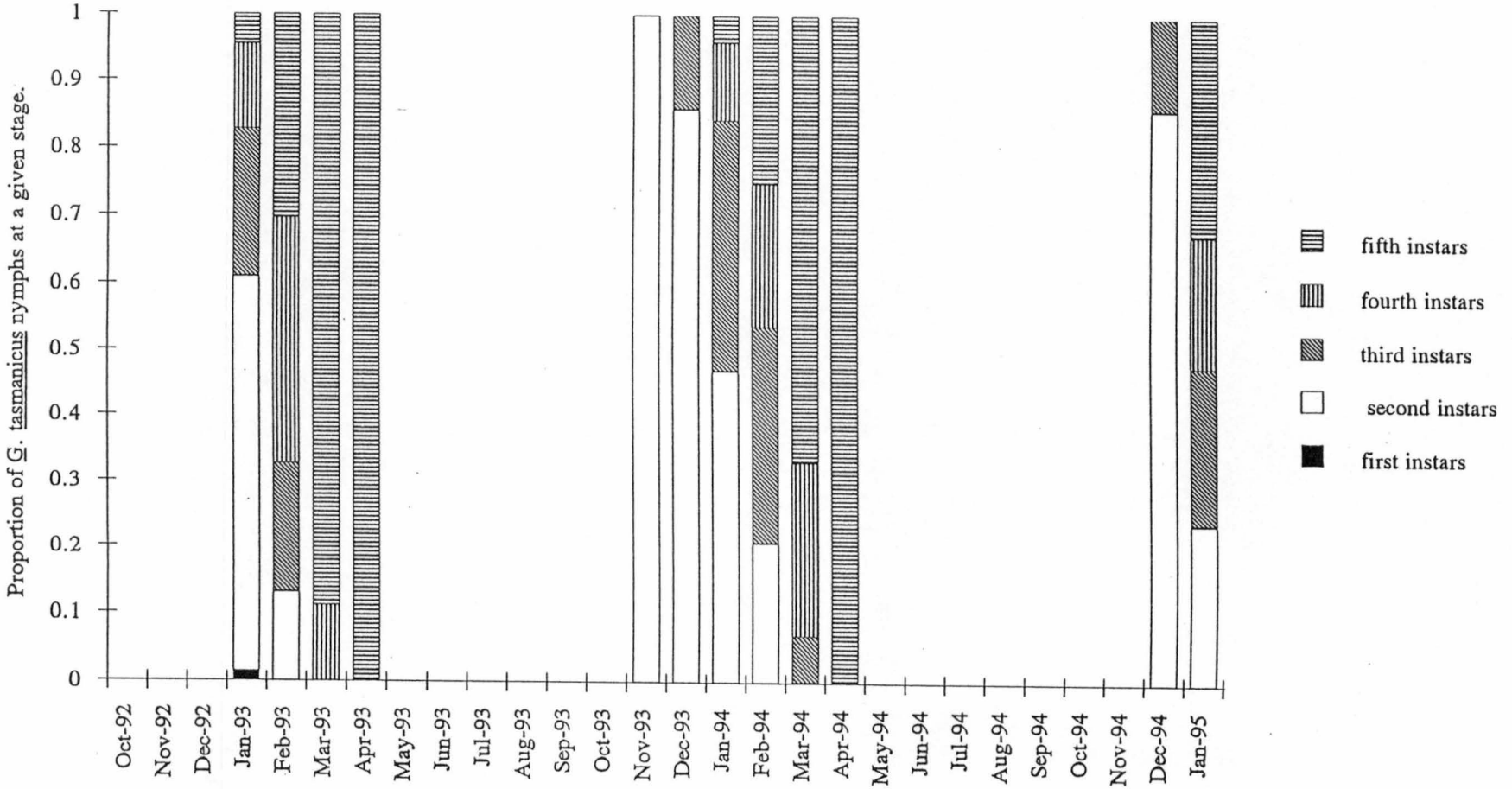


Fig. 4.25. Seasonal changes in the age structure of populations of *G. tasmanicus* nymphs from Tasmania.

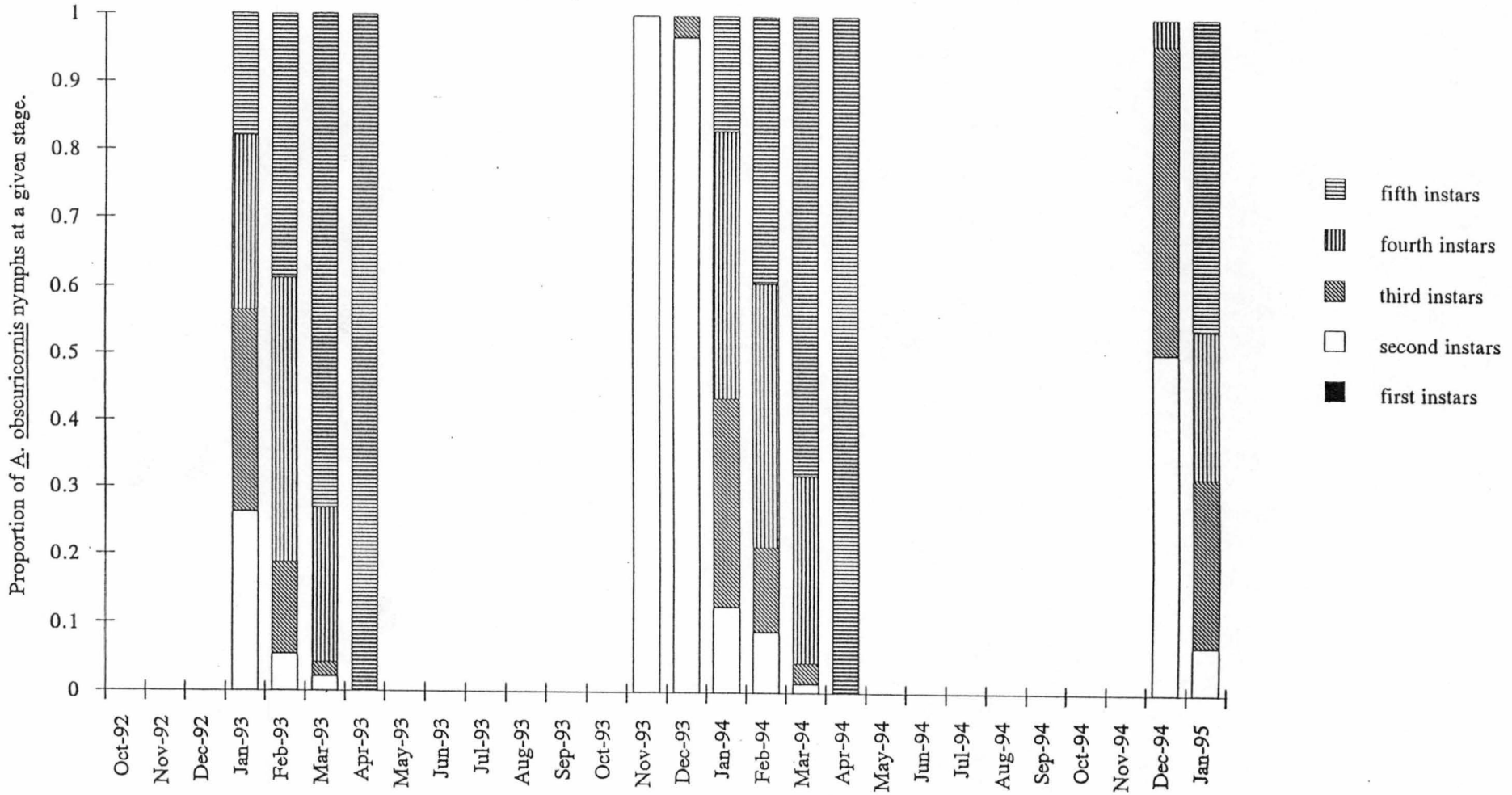


Fig. 4.26. Seasonal changes in the age structure of populations of *A. obscuricornis* nymphs from Tasmania.

4.4. *Discussion*

4.4i. Biogeography of the Genera *Gelonus*, *Acantholybas* and *Amorbus*.

The distributions of *Gelonus* and *Amorbus* on the Australian mainland appear closely linked with that of *Eucalyptus*. This is particularly well illustrated if Fig. 4.4i is compared with Fig. 4.7. This finding strongly supports suggestions that *Eucalyptus* is the dominant host plant genus for these insects. Such a conclusion was also reached by Schaefer and Mitchell (1983). In addition, some species of *Amorbus*, namely *A. rhombifer* and *A. rubiginosus*, have been recorded from plants belonging to the closely related genus *Angophora* (family Myrtaceae). Such reports do not seem particularly surprising given the high degree of similarity between *Eucalyptus* and *Angophora* (Chippendale 1988). Such a close association between plant and insect necessitates that the environmental factors which control plant growth and development also significantly influence the coreids associated with specific eucalypts.

Of the three genera, *Acantholybas* would appear to have the most disjunct geographical distribution with one species apparently endemic to Lombok Island (Indonesia), one to northern New South Wales/southern Queensland and one in Tasmania. Given that Australia has not had direct land contact with Asia since the early Tertiary (50 million years BP) (Keast 1959) it must be assumed that the members of this genus were once much more widely distributed than at present. The host plants of *Acantholybas* are not known, thus it is not possible to comment further upon the factors which may have influenced the distribution of members of this genus. As the genus *Eucalyptus* is not endemic to New Zealand (Wood 1959; Chippendale 1988) where *A. brunneus* is established, and given that this species has been recorded feeding upon a number of cultivated exotics in home gardens (see Steinbauer and Clarke In review (back pocket)), it seems likely that eucalypts are not obligate host plants for this species.

4.4ia. Adult Abundance of the Genera *Gelonus* and *Amorbus*.

Limited inference can be drawn from adult collection date records concerning a species seasonal phenology given that immature stages are not represented. The lack of nymphal specimens of known species does not allow the development of a population within a season to be inferred, thus, whether a species is univoltine, bivoltine and/or multivoltine is difficult to ascertain.

Collection date records for adult *G. tasmanicus* extend from October to March on the Australian mainland. Given that the habitat range of *G. tasmanicus* on the Australian

mainland appears mostly restricted to the comparatively cooler and wetter mountainous regions of Vic., A.C.T. and N.S.W., and that adult activity in such habitats mimicks univoltine Tasmanian populations (section 4.4iia), it is probably univoltine in these areas. It is possible that a similar assumption could be postulated regarding the seasonal phenology of *A. obscuricornis* on the Australian mainland, given that these species possess similar distributions and periods of adult activity. On the Australian mainland, other *Amorbus* species may tend towards a multivoltine life cycle the more northerly their distribution extends. Kumar (1966) first suggested this possibility in relation to *A. alternatus* and *A. rubiginosus* from Brisbane (Qld). Relatedly, Lowman (1982) found that the abundance of insect phytophages, including Hemiptera, in subtropical forests fluctuated over a longer period than did insects from cool temperate forests.

A significant factor affecting the expression of active and dormant phases in insect life cycles in Australia is the change from temperate habitats with winter rainfall in the south to tropical habitats with summer rainfall in the north (Davidson 1934). For coreid species living in more northerly habitats, we might expect that the coincidence of adult activity and reproduction with the more favourable "wet season" to be achieved by some form of "aestivation" (Masaki 1980), in contrast to the winter diapause of more southerly species. Monteith (1982) reported finding *Gralliclava australiensis* Dolling (Coreidae), which were in a semiquiescent state, in moist monsoon forest patches of the Northern Territory during the dry winter months. That such seasonal changes in insect activity occur in these regions was first purported by Davidson (1936).

4.4ib. Regions of High *Amorbus* Species Endemism.

Study of the biogeography of *Amorbus* species has shown that *A. alternatus*, *A. atomarius*, *A. obscuricornis*, *A. rhombifer*, *A. robustus*, *A. rubiginosus*, *Amorbus* n. sp. 3 and *Amorbus* n. sp. 6 have all been collected from regions in southern New South Wales, with many records from the Great Dividing Range (see species distribution maps in Appendix 3 and Fig. 4.7). Interestingly, this distribution corresponds to the "near-coastal regions of N.S.W." where Chippendale (1988) notes that *Eucalyptus* attains its greatest diversity. Carver *et al.* (1991) note that of the Coreinae, only *Amorbus* appears to have undergone any degree of evolutionary radiation in Australia. These findings lend support for hypothesising that the evolutionary radiation of *Amorbus* has followed the radiation of their principal host plants, the eucalypts (see Hill 1994).

Within the south-western region of Western Australia only *A. bispinus*, *A. rubiginosus*

and *Amorbus* n. sp. 4 have been found. This region is also noted by Chippendale (1988) as an area of high eucalypt diversity. As *Amorbus* species diversity seems comparatively low in this region it appears that some factor other than the presence of species of *Eucalyptus* may have been important in determining the success of coreids within this area. As many of the *Amorbus* records from New South Wales come from comparatively cool regions, with high rainfall, it is possible that this factor could be important in differentiating the two zones (as south-west W.A. has a Meditteranean climate, Gentilli 1972) and has influenced the success of coreids in the two areas. As mentioned previously, temperature is considered to be extremely important in determining the distributions of all species (Jeffree and Jeffree 1994), however, the affect of other environmental variables should not be ignored. For example, Specht and Brouwer (1975) found that shoot growth of eucalypts is not only regulated by mean daily temperature but also the intensity of solar radiation and available water. As *Amorbus* species appear to feed exclusively upon eucalypt shoots, environmental factors which impact on eucalypt growth must be very important to the survival and reproduction of these insects.

4.4ii. Biogeography of *Gelonus tasmanicus*, *Acantholybas kirkaldyi* and *Amorbus obscuricornis* in Tasmania.

The distribution of *G. tasmanicus* and *A. obscuricornis* in Tasmania is biased towards the eastern half of the state. These regions mostly correspond to those referred as BEN, CH, DE, FRE, FUR, TM and WOO by Thackway and Cresswell (1995) (see Fig. 4.1). Few specimens of the two species have been collected in the WSW region which is typically very humid/cold and where the vegetation is mostly rainforest, scrub and buttongrass moorlands. When the distribution of these coreids is compared to Kirkpatrick and Dickinson's (1984) distribution of Tasmanian plant communities (Fig. 4.2) there appears a high degree of correlation between the distribution of sclerophyll forest and that of *G. tasmanicus* and *A. obscuricornis*. It may also be possible that the relatively large number of collection records for both species, in particular *A. obscuricornis*, from the south-east of the state reflects the comparatively high diversity of eucalypt species in this region (Davidson *et al.* 1981) and not be solely due the comparatively higher human population levels in this area and/or sampling bias. Relatedly, the apparent non-preference of *G. tasmanicus* for peppermint eucalypts (Chapters 6 and 7) may explain some of the observed differences in collection localities between the two species. For example, many species of peppermint typically inhabit dry sclerophyll forests, whereas ashes and some gums prefer higher rainfall habitats (Table 4.2). Such differences may partly explain the somewhat more westerly distribution of collection localities for *G. tasmanicus*.

Given that both *Gelonus* and *Amorbus* appear to feed almost exclusively upon *Eucalyptus*, it is reasonable to assume that the events which have been important in determining the present day distributions of eucalypts have also determined those of these coreid species. For example, when considering the current distribution of *A. obscuricornis* and *G. tasmanicus* it is necessary to remember the history of events which influenced the present day distribution of eucalypts in Tasmania and on the mainland (Table 4.5).

Table 4.5. Geological history of the land bridge between Tasmania and the Australian mainland during the Tertiary and the palaeobotany of *Eucalyptus*.

Period	Years before present	Event
Paleocene	65-60 million	- Emergence of *Eucalyptus* (Martin 1994)
Oligocene-Miocene	35-20 million	- Major radiation of eucalypts (Wood 1959) - Eucalypts belonging to the Corymbosae in Tas. (Wood 1959; Burbidge 1960) -Land bridge between Tas. and Australian mainland severed (Barlow 1981; Wilford and Brown 1994)
Pleistocene	1.6-0.01 million	- Onset of colder climate associated with ice age (disappearance of warmer adapted eucalypts from Tas. (Burbidge 1960)).
Pleistocene	20-18 thousand	- Land bridge between Tas. and Australian mainland re-established (sea levels 125 m lower than present (Davies 1974)).
Pleistocene	13.5-12 thousand	- Land bridge between Wilsons Promontory (Vic.) and Flinders Island (Tas.). severed (Davies 1974).
Holocene	7380	- Sea levels attained present height (Davies 1974).

Using the information in Table 4.5 it is possible to speculate on the origin of the present day distributions of *A. obscuricornis* and *G. tasmanicus*. Given that insects belonging to the order Hemiptera are older than plants belonging to the genus *Eucalyptus* (pentatomorph fossils belonging to the Aradidae date from the upper Cretaceous, approximately 100-65 million years BP (Kukalová-Peck 1991)) it could be assumed that ancestral *Amorbus* and/or *Gelonus* species were in existence from the earliest times following the appearance of the eucalypts. Therefore ancestral *Amorbus* and/or *Gelonus* species may have arrived in Tasmania before the initial rise in sea level separated the two land masses some 25 million years ago. Whilst Tasmania was separated from the Australian mainland, an ice age during the Pleistocene brought about a lowering of ambient temperatures and concomitant lowering of sea levels. During this period the colder climate may have brought about extinction of some ancestral eucalypts in Tasmania (Burbidge 1960; Barlow 1981). It may also have been during this period that

A. obscuricornis and *G. tasmanicus* first appeared. With the re-establishment of the land bridge with the Australian mainland *A. obscuricornis* and *G. tasmanicus* were able to expand into the cooler regions of the Great Dividing Range and Snowy Mountains. Mainland *Amorbus* species may have been prevented from expansion into pleniglacial Tasmania because of limited forested regions/habitat diversity (Davies 1974; Barlow 1981) and the cold climate. With the severance of the land bridge between Australia and Tasmania some 13.5 to 12 thousand years ago what were single populations of *A. obscuricornis* and *G. tasmanicus* were divided into mainland and Tasmanian populations.

Such an hypothesis for the origins of *A. obscuricornis* and *G. tasmanicus* suggests that both species are essentially Tasmanian in origin which would explain their apparent tolerance of cooler habitats in comparison to mainland species. This scenario would also support speculation concerning possible darker colouration of Tasmanian *A. obscuricornis* in comparison to mainland forms (see Chapter 3) and appears to be similar to the distributional history proposed for *Arctocorisa carinata* (C. Sahlberg) (Corixidae) (Jansson 1980). If *A. obscuricornis* and *G. tasmanicus* are adapted to cooler climates, this would also explain why the presence or absence of a given eucalypt species in any particular mainland state may not be the only factor determining the presence or absence of these insects. For example, although the natural distributions of *E. obliqua* and *E. viminalis* extend some way into S.A. no records of *G. tasmanicus* are presently known from this state. Similarly, although one record of *A. obscuricornis* from S.A. is known, this species does not appear particularly abundant despite the presence of host eucalypt species such as *E. ovata* and *E. viminalis*. These findings suggest that abiotic environmental factors are not only important in influencing the distribution of coreid eucalypt host plants, but also affect the distribution of the coreids themselves.

Alternatively, it is possible that both species arose on the Australian mainland, presumably in the Great Dividing Range and Snowy Mountains, and subsequently expanded into Tasmania at sometime when the two land masses were joined. Such an hypothesis would also support both species' apparent "cold tolerance" and accords with theories concerning the evolutionary radiation of the eucalypts (Hill 1994).

4.4iia. Seasonal Phenology of *Gelonus tasmanicus*, *Acantholybas kirkaldyi* and *Amorbus obscuricornis* in Tasmania.

Both *G. tasmanicus* and *A. obscuricornis* exhibit a univoltine life cycle where adults are the overwintering stage. The majority of overwintering adults emerge in early/mid spring

to commence mating and oviposition. Eggs are presumed to be laid in early/mid spring, hatching in mid/late spring. Nymphs pass through five instars to become adults in early to mid autumn. These conclusions are supported by the earlier works of Green (1972) and Bashford (1992). Given such a life history there must, by necessity, be some form of diapause in the overwintering adults of *G. tasmanicus* and *A. obscuricornis*. Given that copulatory behaviour has been recorded in both species during mid to late summer (see Chapter 5) and that some adults which eclose during mid summer may commence oviposition (see below), there is evidence to suggest that many adults are sexually mature prior to overwintering and may therefore enter a reproductive diapause.

Observations from the field suggest that some adults of *A. obscuricornis*, which eclose during mid summer (i.e. January), may lay a few eggs prior to the onset of autumn. Nymphs from these eggs are collected as second instars during late summer (February) and early autumn (March), however, it seems unlikely that they survive the winter. As eggs laid by early maturing ♀♀ hatch prior to the onset of winter it seems unlikely that there is any overwintering in the egg stage. These observations suggest that under field conditions both *G. tasmanicus* and *A. obscuricornis* conform to Woodward's (1952) 2.i.a. life cycle scenario. That is, both species are univoltine and have long-lived, overwintering, adults. According to Woodward (1952) in overwintering adults of such species there is either a complete inhibition of egg rudiments until spring, or their development is interrupted and/or notably retarded during winter. This enables the formation and oviposition of mature eggs to be delayed until spring. Adults then oviposit in the spring and/or summer. On one occasion in the glasshouse during the summer of 1994/95, adult *A. obscuricornis* were reared from the "F1" progeny of parent insects collected from the field. Thus, in this instance, the insects exhibited a bivoltine life cycle, a condition presumably only possible because of the warm conditions provided by the glasshouse environment.

The phenology of *A. kirkaldyi* cannot be commented upon until further details are obtained. It seems probable, however, that this species will also be found to be univoltine with the adults being the overwintering stage. Such a phenology was proposed for *A. brunneus* in Auckland by Woodward (1953) which has a similar latitude to Tasmania.

Chapter 5

Developmental and Reproductive Biologies of *Amorbus obscuricornis* and *Gelonus tasmanicus*

Chapter 5

Developmental and Reproductive Biologies of *Amorbus obscuricornis* and *Gelonus tasmanicus*

5.1. *Introduction*

5.1i. Developmental Biology of the Coreoidea.

The developmental biology of an insect is the process of change from fertilised egg to fully formed adult (Torre-Bueno 1989). As with other members of the Hemiptera, coreids have a hemimetabolous development, that is they exhibit an incomplete or gradual metamorphosis. Hemimetabolous insects have only two distinct immature stages; the egg and nymph. The nymphs of hemimetabolous insects pass through a series of stages, termed stadia or instars, before becoming adults. Sweeney and Schnack (1977) and De Clercq and Degheele (1992) considered that the estimation of the physiological constants relating to egg development in particular, for example the minimum developmental threshold temperature and the number of degree-days (DD) required for hatching, could provide an insight into the evolved temperature preferences of a species. Such preferences have important implications for the ecology of insects, hence, their reason for study.

5.1ii. Developmental Biology of Immature Stages.

5.1iia. Egg.

Coreids are thought to oviposit on various parts of a host-plant, arranging their eggs either in clusters, in chains or singly, with the arrangement of the eggs possibly reflecting the conformation of the oviposition substrate (Miller 1956). *A. obscuricornis* eggs are green when first laid, changing to purple as they mature (Green 1972). Eye-spots become apparent through the chorion early in development, and migrate towards the anterior pole as hatching approaches (Green 1972). The eggs of *A. rubiginosus* are also green when first laid, but soon become light brown and finally a deep brown (Kumar 1966).

The effect of photoperiod on the rate of development of Heteropteran eggs appears to vary according to species. For example, Cobben (1968) reported that the rate of development of eggs of *Notonecta* (Notonectidae) was as long when given complete darkness as that under natural photoperiod, however, Ohm (1956 in Cobben 1968) found that the time to hatching for eggs of *Aphelocheirus aestivalis* F. (Naucoridae) was doubled when exposed to complete darkness.

The effect of humidity upon coreid eggs, specifically, does not appear to have been investigated. Cobben (1968) considered that fluctuations in relative humidity did not significantly influence developmental times for the eggs of species belonging to the Cimicomorpha and possibly also most Pentatomomorpha (infraorder which includes the Coreidae). For example, Atwal (1959) found that humidities ranging from 20 to 80% had no effect on the developmental rate of eggs of *Bagrada cruciferarum* Kirk. (Pentatomidae). Egg viability has, however, been shown to be affected by extremes of humidity (Hinton 1981). For example, the viability of eggs of *Oncopeltus* (Lygaeidae) (Cobben 1968) and *Tingis ampliata* H.-S. (Tingidae) (Eguagie 1972) was adversely affected by humidities below 51%. Relative humidities approaching 100% favour the growth of fungi which may be harmful to egg survival (Hinton 1981).

Fielding and Ruesink (1988) considered that a linear equation accurately described the rate of development of eggs of *Anasa tristis* DeGeer (Coreidae) at different constant temperatures. Using this model these authors estimated that the minimum developmental threshold temperature for eggs of this species was 13.3°C, with 127 DD required for hatching. Fielding and Ruesink (1988) noted that the daily minimum temperature only occasionally fell below this threshold temperature during the oviposition period and that subthreshold egg development was not important in relation to *A. trisitis*. In a similar study, De Clercq and Degheele (1992) also used a linear model to describe egg development of *Podisus maculiventris* (Say) and *P. sagitta* (Fab.) (Pentatomidae). *Podisus maculiventris* was found to have a minimum egg developmental threshold temperature of 10.7°C and required 78.2 DD for hatching, while *P. sagitta* had a minimum threshold temperature of 13.3°C and required 60.9 DD for hatching. These authors suggested that *P. maculiventris* was somewhat better adapted to cold temperatures than was *P. sagitta*. The developmental threshold temperatures estimated using this technique usually differ from the true developmental zero (Beck 1983). This author noted that considerable embryonic development can occur at temperatures below the hatching threshold, but that complete development can not be completed at such low temperatures. Little data exists concerning developmental times for eggs of *Amorbus* and/or *Gelonus*. Kumar (1966) found that eggs of *A. alternatus* hatched after 6 to 15 days (temperature not given), while Bashford (1992) reported that eggs of *A. obscuricornis* kept at 18°C hatched after 3 to 5 days.

5.1iib. Nymph.

Progression of nymphs to the next instar is marked by a moult in which the juveniles cast

their exoskeleton and replace it with a larger exoskeleton. Przibram's rule (1912, in Torre-Bueno 1989) states that "the weight of an insect is doubled during each instar and at each moult all linear dimensions are increased by the ratio 1.26". Juveniles of macropterous (i.e. having large or fully developed hemelytra and wings) Heteroptera pass through a series of five instars before eclosion (Dolling 1991). Nymphal development not only involves an increase in body size but is also associated with the maturation of the genitalia, development of the hemelytra, wings and ocelli and, in some species, an increase in the number of antennal segments (Gross 1975). Based on nymphal Cimicomorpha, Southwood (1956) devised a key using the development of wing pads to determine the instar of heteropteran nymphs. Kumar (1966) commented that Southwood's (1956) key failed to distinguish first and second instars in the eleven heteropteran species he studied, but found the key to be partially applicable to later instars of 9 of the 11 species (which included *A. rubiginosus*). All the nymphal stages of *Pachycolpura*, *Agriopocoris* (Coreidae) and *Hyocephalus* (Hyocephalidae) could not be separated by Kumar using Southwood's key.

Heteropteran nymphs normally feed actively on the same hosts as adults (Kugelberg 1973; Ralph 1976), although some, such as the pentatomid *Nezara viridula* (L.), do not feed during the first instar (Bowling 1980; Lockwood and Story 1986). Bonjour *et al.* (1991) suggested that first instar nymphs of *Anasa tristis* probed and fed on cucurbit host plants, based on histological examinations showing that stylet tracks terminated in vascular bundles. These authors noted that although nymphal stylets reached the vascular bundles of their cucurbit hosts, experimental conditions prevented confirmation of the imbition of fluids from these elements. On numerous occasions in glasshouse studies, first instar nymphs of *A. obscuricornis* were observed probing the leaves of their eucalypt host plants (pers. obs.). As these nymphs did not cause characterisitic apical wilting (Fig. 5.2vi), their feeding behaviour appeared to differ from that of later instars. This observation led me to investigate the host plant requirements of this instar.

Fielding and Ruesink (1988) considered that the development of nymphs of *Anasa tristis* at different temperatures, both in the field and the laboratory, was not readily predicted using a degree-day model, possibly because nymphs could move to warmer microhabitats and/or sun themselves. These authors therefore used a non-linear relationship to predict developmental times of *A. tristis* based on an enzymatic kinetic model (described in Wagner *et al.* 1984). Nymphal development of *Chelinidea vittiger* Uhler (Coreidae) at different temperatures has also been shown to have a non-linear relationship (Carroll and

Wangberg 1981). Differences between observed and predicted growth rates may reflect that developmental rate data derived under constant temperature regimes correlates poorly with development rates measured under fluctuating temperature conditions (Beck 1983; Hagstrum and Milliken 1991).

In the past, attempts to gather developmental rate data for nymphs of *Amorbus* has been made difficult by an inability to rear immatures beyond the second instar (Kumar 1966). Moreover, the inability to rear heteropterans which feed exclusively upon plant sap, even when they are given correct host plants, is not confined to *Amorbus* (Kumar 1966; Mitchell 1980; Carroll and Wangberg 1981; Flanagan 1994). Thus little data concerning nymphal development is available, however, some information is available. Eclosion in *A. obscuricornis* was reported to occur after approximately 3 weeks depending on temperature (Green 1972), while eclosion in *Mictis profana* (F.) (Coreidae) occurs after 38.66 days at temperatures ranging from 24 to 30°C (Flanagan 1994). In this species, the mortality rate was highest in the second instar (Flanagan 1994).

5.1iii. Overwintering Behaviour, Fat Accumulation and Reproductive Biology of Adults.

Little information is available concerning the overwintering habitats of Heteroptera, in particular those of the Coreidae. Wheeler and Stimmel (1988) surveyed fallen magnolia leaves for Heteroptera and collected some 25 species, only one of which belonged to the Coreidae (namely *Leptoglossus fulvicornis* (Westwood)). Most of the individuals collected were hibernating in leaves which had curled in upon themselves. Similarly, Monteith (1982) recorded finding *Gralliclava australiensis* Dolling (Coreidae) in curled leaves and litter in monsoon forest patches in the Northern Territory (Australia).

The fat content of *Cletus punctiger* Dallas (Coreidae) was found to reach a maximum during mid to late spring after insects emerged from their hibernation sites and began feeding on available spring host plants (Ito 1984, 1985). During this period fat content of female bugs reached a maximum of 49.4% of dry weight (DW). With the commencement of the reproductive period during early to mid summer, fat content declined to 25-30% of DW. Fat contents in adults of both sexes increased again during the pre-hibernation period prior to the onset of autumn, with fat content of females reaching approximately 43% of DW. Adult *C. punctiger* rarely feed during winter (Ito 1985) and utilise their fat reserves in order to survive the winter. During this period the autumn accumulated fat reserves were found to decline by 41.9 and 37.5%, respectively, in female and male *C.*

punctiger. A similar survival strategy has been observed in *Lygaeus equestris* (L.) (Lygaeidae) by Solbreck (1972).

Adults of *C. punctiger* not only utilise fat reserves to survive the winter, but also to carry them over the period when spring host plants are becoming scarce and summer host plants are not yet available (Ito 1984). In starvation longevity experiments, Ito (1984) found that the fat content of adult bugs declined from 25 to 11% over a period of a few weeks. Ito concluded from these experiments that insects emerging from hibernation which did not find sufficient spring host plants on which to feed could not accumulate sufficient fat reserves to survive the summer period.

Changes in the fat content of insects are associated with concomitant fluctuations in water content. Wharton (1985) noted that the fat content of an insect is inversely proportional to its water content and that active insects were more likely to have higher water contents than those which were inactive. Reduced water content is believed to be an important factor increasing an insects resistance to cold (Novák 1975). Accumulation of glycerol prior to diapause can also reduce water content thereby increasing cold-hardiness (Frankos and Platt 1976; Wharton 1985). Thus, it was considered important to quantify these physiological changes in this study, together with those concerning fat content.

The timing of Tasmanian coreid adult activity and reproduction in relation to season has been considered in Chapter 4. Here it was suggested that *A. obscuricornis* and *G. tasmanicus* were predominantly univoltine in Tasmania and that adults were the overwintering stage. Given such a life cycle strategy it is reasonable to assume that adults of both species must possess a reproductive diapause (Tauber and Tauber 1976; Beck 1983). Diapause is a physiological adaptation which enables insects to "bridge" favourable time periods, avoiding those which are less suitable (Solbreck 1978).

Adult squash bugs, *Anasa trisits*, typically overwinter in a state of reproductive diapause (Nechols 1987; Fielding 1988). The induction of reproductive diapause in this species was found to be controlled by photoperiod. Fielding (1988) found that short daylengths (12 hr photoperiod) induced immature and mature bugs, as well as adults that had already overwintered and completed diapause, to enter diapause. Induction of diapause in this species resulted in a cessation of oviposition and a halving of metabolic respiration. This author also demonstrated that the critical photoperiod for diapause induction in adult females was affected by temperature and the stage of development at which insects were

exposed to experimental treatments. For example, the number of females which entered diapause was increased if insects were transferred to experimental conditions as new adults, fifth and fourth instars, respectively. The importance of photoperiod on the induction of diapause has also been demonstrated in other Hemiptera (Dingle 1978; Solbreck 1978; Ito 1978, 1986; Ruberson *et al.* 1991). Fielding (1990) demonstrated that diapause termination in *A. tristis* could be achieved by exposing insects to long daylengths. In addition, the prompt termination of diapause was aided by the availability of food. The availability and quality of food has also been found to be an important influence upon the oviposition and migratory behaviour of many bugs (Derr *et al.* 1981); this phenomenon is often referred to as the oögenesis-flight syndrome (Dingle and Arora 1973; Solbreck 1972, 1978).

5.1iv. Chapter Outline.

This chapter investigates aspects of basic biology which regulate the timing of life history events in *A. obscuricornis* and *G. tasmanicus* immatures and adults. For example, the developmental biology of eggs and nymphs is investigated in order to estimate the temperature, photoperiod and humidity (the latter two factors were investigated in relation to eggs only) requirements of these stages. Similarly, aspects of adult reproductive biology were examined to ascertain the mechanisms by which adults survive, mate and produce offspring. Preferred temperature/humidity/photoperiod regimes for development and reproduction influence the distribution of each species and help determine how these coreids time their life cycles to match the phenology of their eucalypt hosts. Given that both species are herbivores, it is essential that they maximise their chances of locating hosts which are at the most favourable growth stage for their development. Thus, this chapter is not only relevant to the earlier biogeography and seasonal phenology studies (Chapter 4) but also has important implications for the host plant studies detailed in Chapters 6 and 7.

5.2. *Materials and Methods*

5.2i. Egg Developmental Rate Studies.

The aim of these studies was to determine the influence of photoperiod, relative humidity and temperature on the development of eggs of *A. obscuricornis* and *G. tasmanicus*. Rate data was used to estimate the minimum developmental threshold temperature and number of degree-days required for egg eclosion.

Eggs were obtained from coreids maintained on potted *Eucalyptus regnans* in a glasshouse (see Chapter 2). In all these studies the availability of eggs determined numbers of replicates. Eggs were collected at the same time each day and so ranged in age from 0 to 24 hr. Location of eggs was not difficult as both species oviposited preferentially on the mesh of their cages rather than on their eucalypt host. Following their return to the laboratory, eggs were placed on moist filter paper discs which had been folded into small receptacles (Fig. 5.2iii). Filter paper receptacles were not moistened with water in studies of egg development at different relative humidities. Filter paper receptacles were kept in 7.5 to 9.5 cm diameter covered glass petri dishes in controlled environment cabinets. For *A. obscuricornis*, eggs were observed at the same time each day and cabinet temperature, time to appearance of eye-spots, purple egg stage and hatching were recorded. As eggs of *G. tasmanicus* are non-transparent, no records of pre-eclosion development for this species were able to be recorded, so cabinet temperature and hatching time were the only observations made.

5.2ia. Effect of Temperature on Egg Development.

Groups of eggs were placed in controlled environment cabinets with 24 hr photoperiods and exposed to the following temperatures:

A. obscuricornis	*G. tasmanicus*
- 61 eggs at 37.7°C,	- 58 eggs at 29.5°C,
- 115 eggs at 32.0°C,	- 30 eggs at 24.9°C,
- 115 eggs at 19.3°C,	- 39 eggs at 19.3°C,
- 139 eggs with eye-spots at 14.3°C,	- 66 eggs at 9.3°C.

See Chapter 2 for explanation of effective cabinet temperatures. The data from sections 5.2ib and 5.2ic were utilised in conjunction with this information to estimate minimum developmental threshold temperatures and degree-day models for both species. The reciprocal of duration was plotted against temperature for each species and the linear regression equations for the relationships obtained are determined.

5.2ib. Effect of Photoperiod on Egg Development.

This study examined the influence of photoperiod on the development of coreid eggs. Given that eggs of *A. obscuricornis* develop eye-spots during their embryogenesis (Green 1972), the experiment was intended to determine whether visual stimuli influence egg development. Groups of eggs were placed in one of four controlled environment cabinets and exposed to the following photoperiods:

- 115 *A. obscuricornis* and 12 *G. tasmanicus* eggs and given 24 hr light at 26.9°C,
- 115 *A. obscuricornis* and 12 *G. tasmanicus* eggs and given 0 hr light at 24.3°C,
- 115 *A. obscuricornis* and 12 *G. tasmanicus* eggs and given 24 hr light at 14.8°C,
- 115 *A. obscuricornis* and 6 *G. tasmanicus* eggs and 0 hr light at 13.0°C.

Half the cabinets used in this experiment were set for 25°C, the other half for 15°C. Differences in cabinet temperature calibration resulted in the eggs being exposed to the above temperatures (see Chapter 2). Results were thus analysed using Minitab® and the General Linear Model (GLM) where temperature was treated as the covariate (i.e. treated as having one degree of freedom rather than three, Zar 1984; D. Ratkowsky pers. comm.).

5.2ic. Effect of Relative Humidity on Egg Development.

Groups of eggs were placed in a controlled environment cabinet set at 23.5°C and 24 hr photoperiod and exposed to the following relative humidities:

- 20 *A. obscuricornis* and 18 *G. tasmanicus* eggs exposed to approximately 42% RH,
- 20 *A. obscuricornis* and 20 *G. tasmanicus* eggs exposed to approximately 63% RH,
- 20 *A. obscuricornis* and 21 *G. tasmanicus* eggs exposed to 100% RH.

The saturated salt solutions used in section 5.2viib were utilised for this study. Results were analysed using analysis of variance.

5.2ii. Nymphal Instar Determination and Morphometric Study.

The aim of this study was to determine whether the instar of any given coreid nymph could be determined using the key proposed by Southwood (1956). Correct identification of nymphal stages aided development studies as well as the rapid identification of instars in the field. The size of selected morphological features of nymphs of various instars was measured. Materials and methods are detailed in Chapter 2. Illustrations of nymphs of *A. obscuricornis* and *G. tasmanicus* at each instar were made using a camera lucida.

5.2iii. Dietary Intake and Ecdysis Study of First Instar *Amorbus obscuricornis* Nymphs.

The aim of this study was to determine whether first instar *A. obscuricornis* nymphs imbibe water before ecdysis. Incremental changes in body weight prior to and/or at ecdysis are compared to Przibram's theoretical growth factor (Enders 1976; Daly 1985; Torre-Bueno 1989) as well as estimations of incremental growth ratios made using data from the morphometric study.

Newly hatched first instar *Amorbus* nymphs, of known live weight (in mg), were reared in the glasshouse described in Chapter 2 and were subjected to one of the following treatments:

(a) 9 nymphs reared on dry filter paper and kept in 7.5 cm diameter glass petri dishes (no access to free water and/or live plant material and at ambient relative humidity),

(b) 9 nymphs reared on filter paper moistened with distilled water to saturation point (i.e. drip run-off) and kept in 7.5 cm diameter glass petri dishes above water in a sealed plastic container (i.e. access to free water and at 100% relative humidity),

(c) 14 nymphs reared on potted eucalypts (*Eucalyptus morrisbyii* x *E. ovata* and/or *E. morrisbyii* x *E. johnstonii*) in separate cages (i.e. access to live plant material and ambient relative humidity).

Nymphs were reared individually and observed daily until ecdysis. After 4 days each nymph was re-weighed and the time from hatching to ecdysis was recorded. Temperature and humidity records taken from the glasshouse whilst this experiment was being conducted are presented in section 5.2iv.

5.2iv. Nymphal Developmental Rate Studies.

The aim of these studies was to develop a model which would predict the time nymphs of both species took to eclose at any given temperature. The influence of factors such as photoperiod/humidity (as per the egg developmental rate studies) and/or host plant on the rate of development were not investigated because the rearing of nymphs in controlled conditions was found to be extremely difficult and thus precluded the investigation of such factors. Data is presented only for those nymphs which successfully completed a given stadia and is derived mainly from nymphs reared under glasshouse conditions, with some additional nymphs reared in controlled temperature cabinets. All nymphs were reared on potted eucalypts (see Chapter 2).

5.2v. Adult Fat and Water Content Studies.

The aim of this study was to ascertain whether the fat and water contents of adults of *A. obscuricornis* and *G. tasmanicus* fluctuates with season and if so whether any cyclic pattern is apparent. Adult males and females of both species were collected mainly from field sites at Brooks Bay (43°14'S 147°02'E), Darcy Link Rd. (43°21'S 146°56'E), Waterloo (43°12'S 146°58'E) and Sandy Bay (42°55'S 147°20'E) during spring, summer and autumn for fat analysis. Collected insects were stored in a refrigerator if analysis was to be undertaken within 2 days. Alternatively, collected insects were killed, weighed and then wrapped in aluminium foil with an identifying number and frozen at -4°C until analysis. Insects were dried for 4 days in an oven set at 110°C when they were re-weighed in order to estimate percentage water content. Dried insects not able to be placed into the Soxhlet apparatus immediately were kept at 110°C.

The amount of fat in each insect was determined by placing the dried insects in a Soxhlet apparatus to remove the fat using chloroform (as per Edwards 1986a, 1986b, 1988; Edwards and Aschenborn 1988). The specific design of the Soxhlet equipment used follows that described by Carter and Thompson (1953). The insects were removed from the Soxhlet apparatus after 48 hr and re-dried at 110°C for 24 hr. The amount of chloroform-soluble fat was calculated from the difference in the dry weight before and after treatment in the Soxhlet apparatus. Because these insects were difficult to find in the winter months, few analyses were undertaken using insects collected during this period.

5.2vi. Adult Starvation-Longevity Studies.

The aim of these investigations was to ascertain the length of time adults of *A. obscuricornis* and *G. tasmanicus* could survive without feeding. Insects were collected during autumn and it is assumed that they were in either a pre-diapause or diapausing state. These investigations were considered important given that adults are considered to be the overwintering stage. It was hypothesised that the low temperatures and scarcity of vigorously shooting eucalypts during winter may prevent adults from feeding. The length of time these insects were able to survive starvation would then be very important to their ability to overwinter. In the first experiment the importance of temperature upon starvation-longevity was considered. In the second investigation the importance of relative humidity and adult body weight were studied.

5.2via. The Influence of Temperature upon the Starvation-Longevity of Coreid Nymphs and Adults.

The aim of this experiment was to quantify the effect of temperature on the survival longevity of starved, pre-overwintering coreids. Adult *A. obscuricornis* and *G. tasmanicus* (as well as a small number of fifth instar nymphs which were yet to eclose) were collected from field locations in southern Tasmania during autumn 1993. In the laboratory insects were placed in plastic containers, the bases of which were furnished with a moistened filter paper disc on which was written the specimen's number and date of collection. Parafilm was wrapped around the lids of these containers to slow moisture loss. Groups of equal numbers of insects were then assigned at random to one of the following controlled temperature environments: 4.5, 10.6, 14.3 and 19.3°C. Insects were given a 24 hr photoperiod which was necessitated by the lighting system available in the 4.5°C treatment, where lights had to be either on or off. In total, 60 *A. obscuricornis* (30 ♂♂ and 30 ♀♀) and 30 *G. tasmanicus* (15 ♂♂ and 15 ♀♀) were subjected to each of the above treatments. The insects were examined every 24 hr and the numbers which had died recorded. Filter paper discs were moistened with distilled water as required. Analysis of variance was used to test the significance of the results.

5.2vib. The Influence of Relative Humidity and Body Weight upon the Starvation-Longevity of Adult Coreids.

The aim of this experiment was to quantify the effect of relative humidity and body weight on the survival longevity of pre-overwintering coreids. Adults were collected during autumn 1994 and then grouped according to sex and species in the laboratory. Live individuals were weighed using a Mettler AE260 electronic balance and then placed in clean, ventilated, 20 mL glass vials. Vials containing bugs were then placed on metal racks in 10 L plastic containers above saturated salt solutions. Saturated solutions of the following salts were prepared according to the procedure detailed in Winston and Bates (1960): $MgCl_2.6H_2O$; $Ca(NO_3)_2.4H_2O$; NaCl and K_2SO_4 (distilled water was used as the control treatment). At a temperature of 15°C the relative humidity above saturated solutions of these salts should be 34, 56, 76 and 99%, respectively (Winston and Bates 1960). The relative humidity above the distilled water was assumed to be 100%. Using a hygrometer it was found that the relative humidities above the saturated solutions prepared by me were actually 42, 63, 79 and 99%, respectively. The plastic containers were placed in a controlled temperature cabinet set at 15°C and a 24 hr photoperiod. This cabinet maintained a temperature of 14.3 $\pm$ 0.1°C. This photoperiod was used to provide continuity with experiment 5.2via. 10 *A. obscuricornis* ♂♂/13 *A. obscuricornis* ♀♀ and

12 *G. tasmanicus* ♂♂/10 *G. tasmanicus* ♀♀ were then assigned to each of the above treatments. Observations were taken as per experiment 5.2via. Treatment effects were tested using analysis of variance.

5.2vii. Seasonality of Copulatory Behaviour and Fecundity in Coreids.

The aim of these studies was to elucidate the behaviour of *A. obscuricornis* and *G. tasmanicus* adults following their emergence in spring. To this end relative abundance of adult male and female coreids, as well as the number of individuals *in copula*, was recorded routinely when taking seasonal phenology records in the field. The sampling method employed is described in Chapter 2. In addition, the number of gravid females and the number of eggs clearly visible under the dissecting microscope (i.e. eggs at an advanced stage of development) was recorded by dissecting females prior to their drying for fat analyses (see Chapter 2 for method).

5.3. *Results*

5.3i. Egg Developmental Rate Studies.

The eggs of *A. obscuricornis* (Fig. 5.2i) were observed to undergo the same colour development as noted by Green (1972). Eggs of *G. tasmanicus* are a pale blue colour for a short period following oviposition, but turn brown within 2 to 3 hours (Fig. 5.2ii). *A. obscuricornis* eggs have a mean weight of 3.85 $\pm$ 0.04 mg [n = 58], whilst those of *G. tasmanicus* had a mean weight of 1.96 $\pm$ 0.02 mg [n = 51]. In glasshouse studies a few eggs belonging to both species were laid on the plants within their cages. These eggs were laid on leaves and stems, either singularly or in small groups of two to three eggs. The majority of eggs were, however, laid on the mesh walls of the cages.

5.3ia. Effect of Temperature on Egg Development.

The results presented in Table 5.1 detail developmental rates for eggs of *A. obscuricornis* and *G. tasmanicus* at different constant temperatures. A positive, linear, correlation between rate of development and temperature was observed for both species (Table 5.1, 5.2 and 5.3; summarised in Figs 5.1i and 5.1ii). Using the regression equation, the minimum developmental threshold temperature for *A. obscuricornis* was estimated to be 11.8°C (Fig. 5.1i), with 147 DD required for hatching. The rate of development of eggs of *G. tasmanicus* did not remain linear over the full range of temperatures tested. For example, development at 29.5°C was significantly more rapid than a linear relationship would have predicted (Fig. 5.1ii). Thus, the regression equation used to calculate the DD and minimum developmental threshold temperature required for hatching in this species excludes data at this temperature. For *G. tasmanicus*, the minimum developmental threshold temperature was 10.8°C (Fig. 5.1ii) and the number of DD required for hatching was 136.

The validity of incorporating data from section 5.3ib, where eggs were reared in constant darkness, into these models was investigated given that light was found to have a significant effect on development rate. The exclusion of data for *A. obscuricornis* at 24.3°C and 24.3 and 13.0°C for *G. tasmanicus* had relatively little effect on the regression equations obtained (e.g. $y = -0.0796 + 0.00679x$, $r^2 = 0.996$ for *A. obscuricornis* and $y = -0.0833 + 0.00747x$, $r^2 = 0.999$ for *G. tasmanicus*). Similarly, the data for 25.9°C (see section 5.3ic) was excluded from both models to determine the influence upon rate, given that humidity was found to have an effect upon egg development. Removal of this data had relatively little effect on the regression equations given beneath Figs 5.1i and 5.1ii (e.g. $y = -0.0805 + 0.00682x$, $r^2 = 0.996$ for *A.*

obscuricornis and y = - 0.0788 + 0.00732x, r^2 = 0.995 for *G. tasmanicus*). Thus, data from sections 5.3ib and 5.3ic was retained in these models.

Bashford (1992) stated that eggs of *A. obscuricornis* took 3 to 5 days to hatch at 18°C. Using d = DD/(x - b) (where DD is the number of degree-days, x is temperature, b is the species' minimum developmental threshold temperature and d is the days to hatching), *A. obscuricornis* eggs at this temperature should take approximately 23.6 d to hatch. This would suggest that the eggs examined by Bashford were at an advanced stage of development when collected and not recently laid as were the eggs used to develop these models.

5.3ib. Effect of Photoperiod on Egg Development.

The results presented in Table 5.2 summarise the developmental times for eggs of *A. obscuricornis* and *G. tasmanicus* at various photoperiod/temperature regimes. Statistical analysis of the data revealed that the presence or absence of light had a slight, but significant, effect upon the rate of egg development for both species (Table 5.2). Because no eggs of *A. obscuricornis* hatched at temperatures below 15°C, statistical analyses for this species were based on the time to the purple egg stage. In *A. obscuricornis* differences in the time to the purple egg stage due to the influence of light were found to be significant ($F_{1, 332}$ = 376.09, $p < 0.001$), however, this factor was of comparatively minor importance compared to the effect of temperature ($F_{1, 332}$ = 7035.03, $p < 0.001$). The interaction of the two treatments was also significant but of relatively minor importance in relation to temperature ($F_{1, 332}$ = 420.11, $p < 0.001$). Similarly, light had a minor influence upon the rate of egg development of eggs of *G. tasmanicus*. For example, differences in the time to hatching were influenced by light ($F_{1, 40}$ = 62.45, $p < 0.001$), however, this effect was of relatively less significance to that resulting from differences in temperature ($F_{1, 40}$ = 781.44, $p < 0.001$). Again, the interaction between the two factors was also significant ($F_{1, 40}$ = 59.08, $p < 0.001$). These results suggest that the use of constant lighting to incubate coreid eggs, as used in the studies detailed in sections 5.3ia and 5.3ic, is unlikely to significantly influence egg development in comparison to the effect of temperature.

An obvious difference between the two species is that eggs of *A. obscuricornis* did not hatch at 14.3 or 13.0°C, while there was maximal hatch of *G. tasmanicus* eggs at these temperatures. Conversely, as temperature increased from 13.0 to 26.9°C the percentage of *G. tasmanicus* eggs hatching began to decline.

5.3ic. Effect of Relative Humidity on Egg Development.

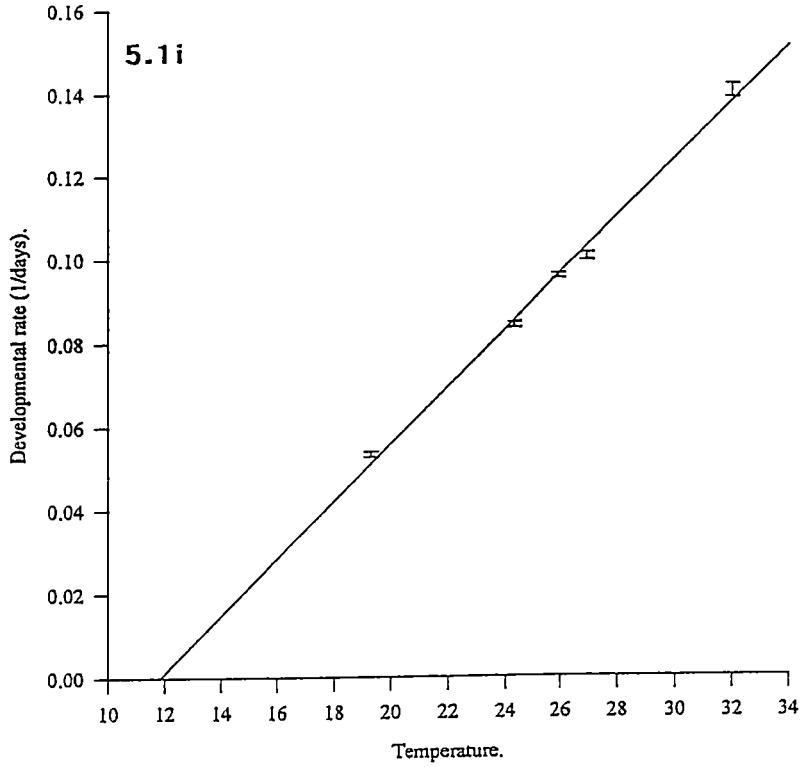
The effect of relative humidity (RH) on the development of eggs of both species is shown in Table 5.3. Analysis of the results for *A. obscuricornis* indicated that relative humidity had a significant effect on the time to appearance of eye-spots ($F_{2, 51} = 4.41$, $p = 0.017$). The early appearance of eye-spots in eggs at 63% RH subsequently lead to their developing at a faster rate than those at the other humidities. Thus, the time to purple egg stage and hatching was also significantly different between humidities ($F_{2, 45} = 51.80$, $p < 0.001$; $F_{2, 50} = 25.85$, $p = 0.001$, respectively). Given that egg development was often very synchronous, variations of a single day were enough to cause treatment means to be statistically different from one another (see ranges given in Table 5.3). For this reason further investigation of the effect of relative humidity on egg development, where development was measured in hours, would be warranted before any sound conclusions could be reached. If it is assumed that the data for *A. obscuricornis* reflects a true difference, then a decrease in egg development rate at 42 and 100% RH might be explained by a lack of humidity retarding embryogenesis and high humidity decreasing egg viability, possibly through disease, respectively. Indeed, some eggs at 100% humidity went black and had opaque hyphae protruding from their surfaces. Egg development was most rapid at 63% RH. Further investigation would also be needed to determine whether relative humidity influences the viability of eggs given that 5 eggs did not hatch at 100% compared to only 1 egg in each of the 42 and 63% RH treatments.

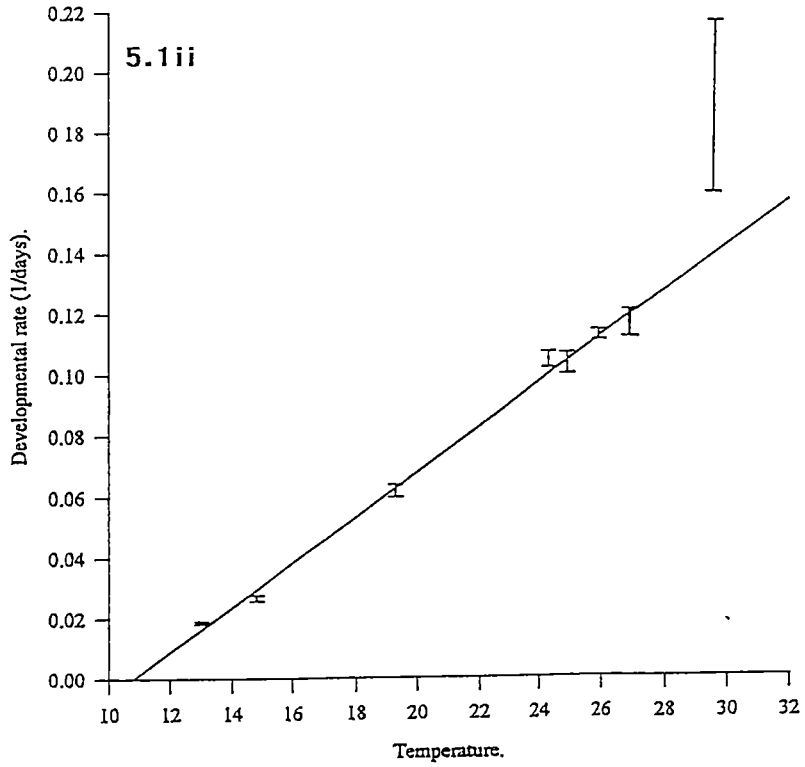
The rate of development of eggs of *G. tasmanicus* was not found to be significantly influenced by relative humidity ($F_{2, 51} = 0.56$, $p = 0.577$) (Table 5.3) which contrasts with the findings for eggs of *A. obscuricornis*. For *G. tasmanicus* there was a slight reduction in percentage hatch of eggs at 42% RH.

These findings suggest that relative humidity may have an influence upon egg developmental rate, however, this effect is probably comparatively small in relation to the effect of temperature. Relative humidity may partly explain the variation in developmental rates of eggs exposed to different constant temperatures given that predicted developmental times vary from those observed at different humidities. In addition, extremes of relative humidity may effect egg viability.

Table 5.1. Development rate of eggs of *Amorbus obscuricornis* and *Gelonus tasmanicus* at different temperatures. Results presented as means ± se. Durations measured in days. Ranges given in parentheses.

Species/temperature	% hatch	Time to eye-spot appearance	Time to purple egg stage	Time to hatching
A. obscuricornis				
37.7°C	0	2.6 ± 0.1 [n = 50] (1-4)	7.6 ± 0.3 [n = 23] (5-10)	-
32.0°C	69.6	2.9 ± 0.1 [n = 108] (1-4)	6.3 ± 0.1 [n = 89] (4-9)	7.2 ± 0.1 [n = 80] (5-8)
19.3°C	90.4	8.1 ± 0.2 [n = 114] (2-13)	17.5 ± 0.2 [n = 108] (12-23)	19.1 ± 0.2 [n = 104] (14-24)
32.0°C/14.3°C	23.0	2.9 ± 0.1 at 32.0°C [n = 124] (1-4)	27.5 ± 0.3 at 14.3°C [n = 117] (13-38)	31.6 ± 1.0 at 14.3°C [n = 32] (13-39)
G. tasmanicus				
29.5°C	56.9	-	-	7.1 ± 0.1 [n = 29] (6-8)
24.9°C	53.3	-	-	9.9 ± 0.3 [n = 16] (7-11)
19.3°C	79.5	-	-	16.8 ± 0.2 [n = 30] (11-18)
9.3°C	0	-	-	-





Figs 5.1i, 5.1ii. Mean developmental rate versus temperature for eggs of: **(5.1i)** *A. obscuricornis* (regression equation y = - 0.0806 + 0.00682x, r^2 = 0.995); **(5.1ii)** *G. tasmanicus* (regression equation y = - 0.0792 + 0.00735x, r^2 = 0.996).

Table 5.2. Development rate of eggs of *Amorbus obscuricornis* and *Gelonus tasmanicus* at different photoperiod/temperature regimes. Results presented as means ± se. Durations measured in days. Ranges given in parentheses. Values within a column followed by the same letter are not significantly different at the 5% level.

Species/treatment	% hatch	Time to eye-spot appearance	Time to purple egg stage	Time to hatching
A. obscuricornis				
24 hr light/26.9°C	97.4	5.1 ± 0.9 [n = 114] (1-7)	9.0[a] ± 0.9 [n = 99] (5-13)	10.1 ± 0.9 [n = 112] (7-12)
0 hr light/24.3°C	93.0	5.9 ± 0.6 [n = 114] (3-7)	11.0[a] ± 1.2 [n = 106] (6-15)	12.0 ± 0.9 [n = 107] (9-15)
24 hr light/14.8°C	0[#]	27.7 ± 3.2 [n = 114] (13-33)	62.7[b] ± 5.0 [n = 102] (46-82)	-
0 hr light/13.0°C	0	43.3 ± 7.8 [n = 108] (5-56)	97.4[c] ± 3.2 [n = 26] (74-127)	-
G. tasmanicus				
24 hr light/26.9°C	58.3	-	-	8.7[a] ± 0.8 [n = 7] (7-9)
0 hr light/24.3°C	75.0	-	-	9.7[a] ± 0.7 [n = 9] (9-11)
24 hr light/14.8°C	83.3	-	-	38.0[b] ± 4.4 [n = 10] (32-44)
0 hr light/13.0°C	83.3	-	-	54.0[c] ± 2.7 [n = 5] (52-57)

in 11.3% of eggs the pseudoperculum lifted partly after 68.7 ± 4.5 d but eclosion was not achieved.

Table 5.3. Development rate for eggs of *Amorbus obscuricornis* and *Gelonus tasmanicus* at different relative humidities. Results presented as means ± se. Durations measured in days. Ranges given in parentheses. Values within a column followed by the same letter are not significantly different at the 5% level. The average temperature in the cabinet during this experiment was: 25.85 ± 0.04°C, n = 51.

Species/relative humidity	% hatch	Time to eye-spot appearance	Time to purple egg stage	Time to hatching
A. obscuricornis				
42%	95.0	5.0^{a} [n = 19]	9.8^{a} ± 0.1 [n = 13] (9-10)	10.6^{a} ± 0.1 [n = 19] (10-11)
63%	95.0	4.8^{b} ± 0.1 [n = 19] (4-5)	9.1^{b} ± 0.1 [n = 19] (9-10)	10.1^{b} ± 0.1 [n = 19] (10-11)
100%	75.0	5.0^{a} [n = 16]	9.9^{a} ± 0.1 [n = 16] (9-10)	10.9^{a} ± 0.1 [n = 15] (10-11)
G. tasmanicus				
42%	94.4	-	-	9.0^{c} ± 0.3 [n = 15] (7-10)
63%	100	-	-	8.9^{c} ± 0.1 [n = 19] (8-9)
100%	100	-	-	9.2^{c} ± 0.3 [n = 20] (7-10)

Figs 5.2i-5.2vi. Photographs of: **(5.2i)** an *A. obscuricornis* egg with eye-spot, aero-micropylar processes apparent (Cobben 1968) at margin of pseudoperculum (scale line interval = 1 mm); **(5.2ii)** a *G. tasmanicus* egg, rim of pseudoperculum apparent (scale line interval = 1 mm); **(5.2iii)** eggs of *A. obscuricornis* at various stages of development; **(5.2iv)** first instar nymphs of *A. obscuricornis*; **(5.2v)** a newly ecdysed second instar *A. obscuricornis* nymph prior to sclerotization; **(5.2vi)** a fully sclerotized second instar *A. obscuricornis* nymph feeding upon a shoot of *E. pulchella*.

5.3ii. Nymphal Instar Determination and Morphometric Study.

Southwood's (1956) key was found suitable to determine the instar of nymphs of *A. obscuricornis* and *G. tasmanicus*. Although separating first and second instars of *G. tasmanicus* requires some practice, such a problem does not exist for *A. obscuricornis*, given that first instars are a distinctive green and black colour. The development of wing pads was thus used to identify nymphs of both species throughout this study. Figures 5.3i to 5.3x illustrate the progressive development of wing pads of nymphs of *A. obscuricornis* and *G. tasmanicus*.

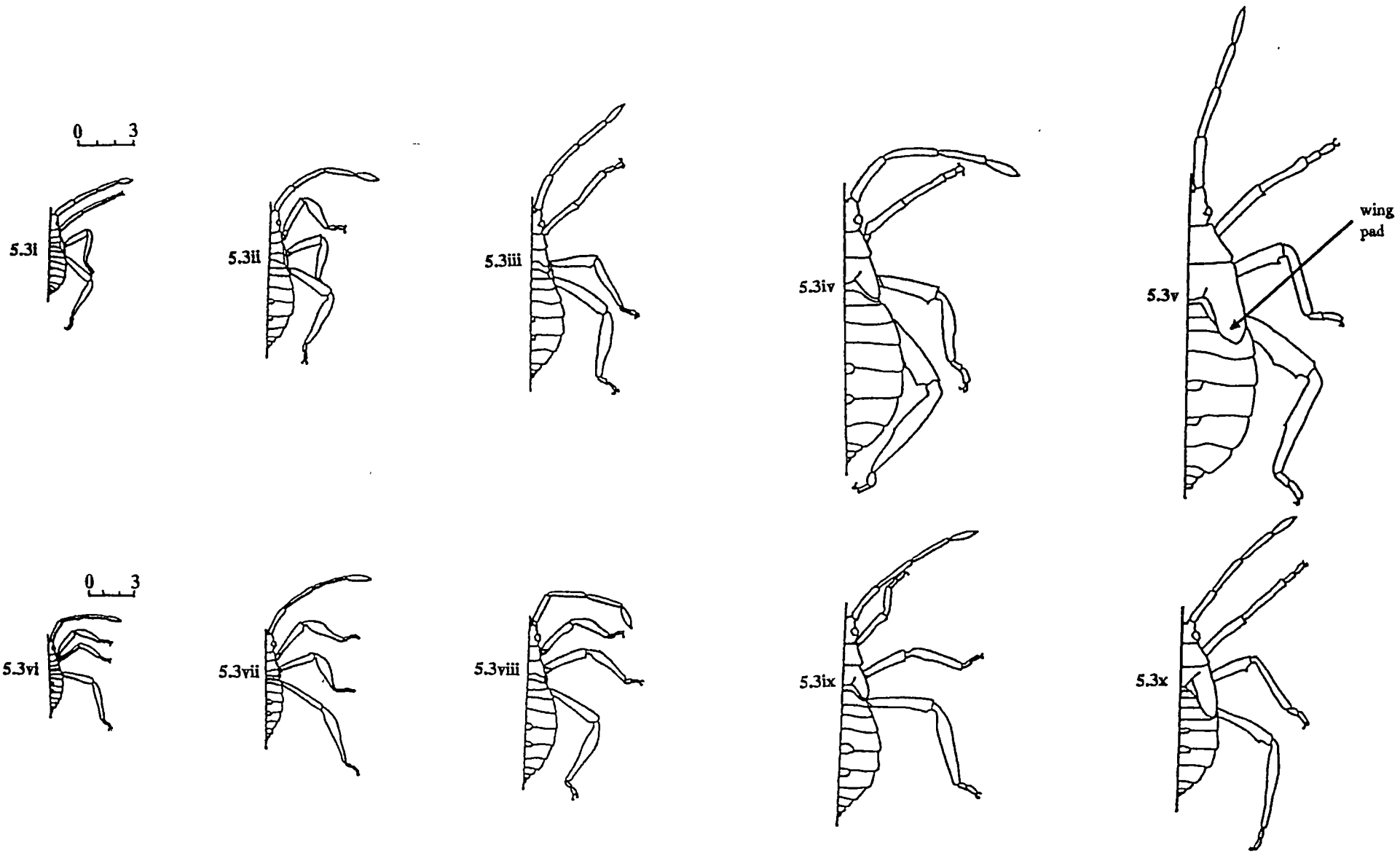
Table 5.4 summarises the morphological information pertaining to *A. obscuricornis* nymphs at various stages of development. Of the five features measured, head width was the least variable across all instars, followed by apical antennal length and pronotum width. Mid and hind femora lengths were the most variable of the features measured. The influence of sex upon the size of fifth instar *A. obscuricornis* nymphs can be seen from the results presented in Table 3.3, Chapter 3.

Unlike nymphs of *A. obscuricornis*, the head widths of nymphs of *G. tasmanicus* were not found to be the least variable of the features measured, but rather apical antennal segment length (Table 5.4). Nymphs of this species were found to have very variable mid and hind femora.

Amongst the factors responsible for variation between individuals, in addition to sex, is collection locality and year, as Table 5.5 illustrates. Linear Discriminant Analysis (Minitab®), using collection site as the group predictor, demonstrated that each of the 16 individuals could be accurately classed to collection locality based on the morphometric data. Collection locality will determine the range of eucalypt species available for nymphs to feed upon, while year of collection may influence factors such as ambient temperature and rainfall. These latter factors significantly influence both plant and nymphal growth rates.

Table 5.4. Summary of morphometric measurements of external morphological features of *Amorbus obscuricornis* and *Gelonus tasmanicus* nymphs. Measurements (in mm) presented as means ± se. Ranges given in parentheses.

Species/feature	I instar	II instar	III instar	IV instar	V instar
A. obscuricornis	[n = 3]	[n = 20]	[n = 22]	[n = 29]	[n = 73]
apical antennal length	0 87 ± 0.02 (0.85-0.90)	1.12 ± 0.01 (1.05-1.20)	1.40 ± 0 02 (1.30-1.55)	1.76 ± 0.02 (1.55-1.90)	2.10 ± 0.02 (1.70-2.65)
head width	0.88 ± 0.03 (0.85-0.95)	1.04 ± 0 01 (1.00-1.10)	1 27 ± 0.01 (1 20-1 30)	1.58 ± 0.01 (1.50-1.65)	1.84 ± 0.01 (1.65-2.10)
pronotum width	0.92 ± 0.03 (0.85-0.95)	1.12 ± 0.01 (1.05-1 20)	1.60 ± 0 01 (1.45-1.70)	2.47 ± 0.02 (2.20-2.65)	3.78 ± 0.04 (3.00-4.60)
mid femur length	1.63 ± 0.03 (1.60-1.70)	2.25 ± 0.02 (2.10-2.35)	2.91 ± 0 03 (2 65-3 15)	3.71 ± 0.03 (3.40-4.15)	4 18 ± 0.05 (3.45-5 00)
hind femur length	1.88 ± 0.04 (1.80-1.95)	2.75 ± 0.02 (2.60-2.95)	3.72 ± 0.03 (3.35-4.00)	4.84 ± 0.10 (4.45-5.10)	5.43 ± 0.06 (4.55-6.60)
G. tasmanicus	[n = 13]	[n = 5]	[n = 8]	[n = 8]	[n = 10]
apical antennal length	0 87 ± 0.01 (0.80-0.90)	1.02 ± 0.01 (1.00-1.03)	1.21 ± 0 02 (1.13-1.30)	1.44 ± 0.02 (1 37-1.53)	1.75 ± 0 01 (1.70-1.80)
head width	0.82 ± 0.01 (0.75-0.85)	0.90 ± 0.01 (0.87-0.93)	1.11 ± 0.02 (1.00-1.20)	1.37 ± 0.02 (1.30-1.45)	1.63 ± 0.03 (1.50-1.75)
pronotum width	0.79 ± 0.01 (0.70-0.90)	0.87 ± 0.02 (0 83-0.90)	1 20 ± 0.02 (1.10-1.30)	1.78 ± 0.03 (1.60-1.90)	2.71 ± 0.08 (2.35-3.10)
mid femur length	1.55 ± 0.02 (1.40-1.65)	1.72 ± 0.02 (1.65-1.75)	2.30 ± 0 09 (2.05-2.75)	2.70 ± 0.10 (2.40-3.15)	3.43 ± 0.04 (3.20-3.55)
hind femur length	1.93 ± 0 02 (1.80-2.05)	2.28 ± 0.04 (2.20-2.40)	2.95 ± 0.11 (2.60-3.45)	3.54 ± 0.11 (3.20-4 05)	4 35 ± 0.06 (4.05-4.55)



Figs 5.3i-5.3x. Line diagrams of *Amorbus obscuricornis* nymphs (top): (5.3i) first instar, (5.3ii) second instar; (5.3iii) third instar; (5.3iv) fourth instar; (5.3v) fifth instar (♂). Line diagrams of *Gelonus tasmanicus* nymphs (bottom): (5.3vi) first instar; (5.3vii) second instar; (5.3viii) third instar; (5.3ix) fourth instar; (5.3x) fifth instar. (Scale line intervals = 1 mm.)

Table 5.5. Summary of morphological features of V instar ♂ *Amorbus obscuricornis* nymphs from different collection sites and years. Measurements (in mm) presented as means ± se. Ranges given in parentheses. (N.B. nymphs dated 1979 collected by R. Bashford, Forestry Tasmania.)

Feature	Cambridge, 1979 S.E. Tasmania n = 10	Goulds Country, 1989 N.E. Tasmania n = 6
apical antennal length	2.42 ± 0.04 (2.30-2.65)	2.09 ± 0.05 (2.00-2.30)
head width	1.96 ± 0.02 (1.85-2.05)	1.81 ± 0.02 (1.70-1.85)
pronotum width	4.19 ± 0.04 (4.00-4.40)	3.75 ± 0.05 (3.55-3.90)
mid femur length	4.73 ± 0.05 (4.50-4.95)	4.20 ± 0.05 (4.05-4.35)
hind femur length	6.13 ± 0.08 (5.90-6.60)	5.43 ± 0.05 (5.30-5.60)

5.3iii. Dietary Intake and Ecdysis Study of First Instar *Amorbus obscuricornis* Nymphs.

The results presented in Table 5.6 clearly show that the availability of moisture is a critical factor in the successful ecdysis of first instar *A. obscuricornis* nymphs. For example, nymphs which had similar live weights at the commencement of the experiment ($F_{2, 29} = 0.81$, $p = 0.454$) weighed significantly more after 4 days when provided access to either saturated filter paper and/or live plants ($F_{2, 29} = 37.86$, $p < 0.001$). This difference in weight gain is even more apparent when the ratio of weight after 4 days to initial weight is compared for these same nymphs ($F_{2, 29} = 48.77$, $p < 0.001$). Nymphs given no access to free water and/or live plants (treatment **a**) and which were kept at ambient relative humidity survived for two to three days and then died (Table 5.6).

Table 5.6. Weight and survival of first instar *Amorbus obscuricornis* at three different rearing conditions. Results presented as means ± se. Live weights in mg and durations measured in days. Ranges given in parentheses.

Treatment	A: initial live weight	B: weight at 4 days	Ratio B : A	Time to ecdysis	% ecdysing
(a) - no free water - no live plants - ambient humidity n = 9	2.90 ± 0.07 (2.7-3.3)	2.40# ± 0 07 (2.0-2.6)	0.83 ± 0.01 (0.74-0.90)	-	0†
(b) - free water - no live plants - 100% humidity n = 9	2.93 ± 0.10 (2.5-3.4)	5.27 ± 0.44 (4.2-8.0)	1.80 ± 0.13 (1.29-2.58)	4.00* n = 8	100
(c) - no free water - live plants - ambient humidity n = 14	2.79 ± 0.08 (2.5-3.3)	4.63 ± 0.10 (3.9-5.4)	1.67 ± 0.04 (1.39-1.85)	4.93 ± 0.13 (4-6)	100

nymphs weighed at death.
† nymphs survived 2.78 ± 0.15 d (range 2-3 d) before dying.
* 2 nymphs ecdysed malformed; these nymphs had more than doubled their initial weights and were the heaviest individuals within this treatment (live weights = 6.6 and 8.0 mg after 4 days, respectively).

First instar nymphs which had had access only to free water (treatment **b**) were able to ecdyse and did so sooner than those nymphs given access to live plants and kept at ambient humidity (treatment **c**) ($F_{1, 20} = 29.98$, $p < 0.001$). Although these results do not conclusively show that first instar nymphs do not ingest carbohydrates from plants prior to ecdysis, they do indicate that this stadia apparently has little need to do so.

The ratio of B : A in Table 5.6 represents the incremental change in live weight prior to or at ecdysis. As is apparent, the weight ratios for treatments **b** and **c** approximate a two-fold increase. Similarly, using the previous morphometric data it is clear that the dimensions measured also approximate Przibram's theoretical progression factor of 1.26 for both *A. obscuricornis* and *G. tasmanicus* (Table 5.7). These findings support suggestions concerning the importance of weight change by water intake in the ecdysis of first instar nymphs of *A. obscuricornis*.

Table 5.7. Summary of estimated Przibram's progression of growth factors, using head width, for *Amorbus obscuricornis* and *Gelonus tasmanicus* (N.B. Przibram's (1912, in Torre-Bueno 1989) rule gave a theoretical progression factor of 1.26 for insects in general).

Ratio	*A. obscuricornis*	*G. tasmanicus*
II/I	1.04/0.88 = 1.18	0.90/0.82 = 1.10
III/II	1.27/1.04 = 1.22	1.11/0.90 = 1.23
IV/III	1.58/1.27 = 1.25	1.37/1.11 = 1.23
V/IV	1.84/1.58 = 1.16	1.63/1.37 = 1.19
adult*/V	2.04/1.84 = 1.11	1.83/1.63 = 1.12
mean ± se	1.18 ± 0.02	1.17 ± 0.03

* adult head measurements taken from Chapter 3.

5.3iv. Nymphal Developmental Rate Studies.

The results of the previous study (section 5.3iii) revealed that, provided first instar nymphs of *A. obscuricornis* had access to moisture, ecdysis would occur in the absence of plant material. Thus, nymphs need only get access to plants as second instars and the following studies were based on this assumption. Rearing trials (see Chapter 2) clearly demonstrated that second instar nymphs of *A. obscuricornis*, and possibly also *G. tasmanicus*, must have access to live plants in order to grow. The only nymphs successfully reared to eclosion were those kept on potted eucalypts. Second instar nymphs were not able to develop on excised eucalypt shoots. The starvation longevity of *A. obscuricornis* nymphs on excised shoots was often similar to that of nymphs denied access to all plant material, suggesting that no effective feeding occurred. Table 5.8 summarises instar durations for those nymphs which successfully ecdysed.

Nymphs of *A. obscuricornis* were least able to mature at 14.8°C, only one of 28 first instar nymphs successfully ecdysed at this temperature. In contrast, nymphs of *G. tasmanicus* readily ecdysed to the second instar at this temperature. The duration of some stadia was observed to be very variable in *A. obscuricornis* nymphs. Generally, most first instar nymphs at a particular temperature ecdysed within a few days of one another, however, this was not the case for later instars. Stadia duration was affected by ambient environmental conditions; for example, second instar *A. obscuricornis* nymphs reared in controlled temperature rooms at 16 hr photoperiod and 21.8°C could take up to 46 d to ecdyse, whereas similar nymphs at 24 hr photoperiod and 19.3°C took up to 22 d to ecdyse. Nymphs of *A. obscuricornis* which failed to eclose predominantly died as second instars. Few nymphs of *G. tasmanicus* progressed beyond ecdysis to the second instar. If

A. obscuricornis nymphs first require plant derived nutrients only as second instars (as suggested by section 5.3iii) the successful initiation of feeding may be a critical stage in nymphal development and could explain the comparatively higher mortality rate for second instars (also reported by Flanagan 1994).

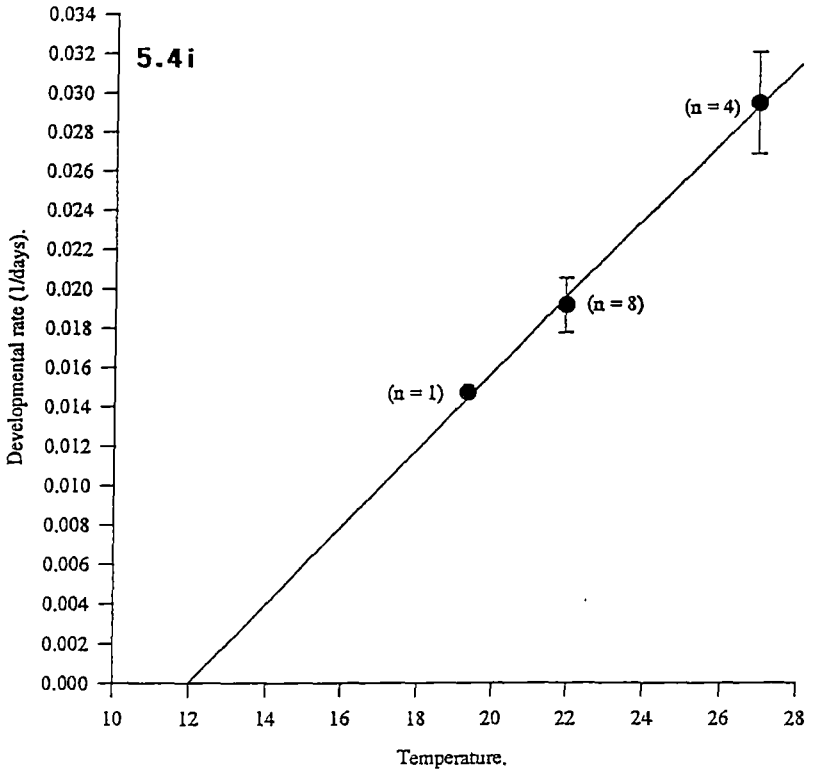
One of the initial aims of these studies was to determine the developmental duration of the nymphal stages of *A. obscuricornis* and *G. tasmanicus* at different constant temperatures. The difficulty experienced rearing nymphs of these species has had a significant influence upon the attainment of this aim. This was especially pertinent in the rearing of *G. tasmanicus*, i.e. no adult insects could be reared using any of the techniques trialled. These difficulties have, therefore, made it possible to provide only a rough estimate of the influence of temperature on nymphal development for *A. obscuricornis* (Fig. 5.4i). The limited number of points available prevent determination of the suitability of models (such as that used by Fielding and Ruesink 1988) other than a straight line relationship. Using the regression equation the number of degree-days and minimum developmental threshold temperature required for eclosion of *A. obscuricornis* was estimated as 509 DD and 12.0°C, respectively. These figures can only be regarded as estimates and need to be improved by additional developmental data.

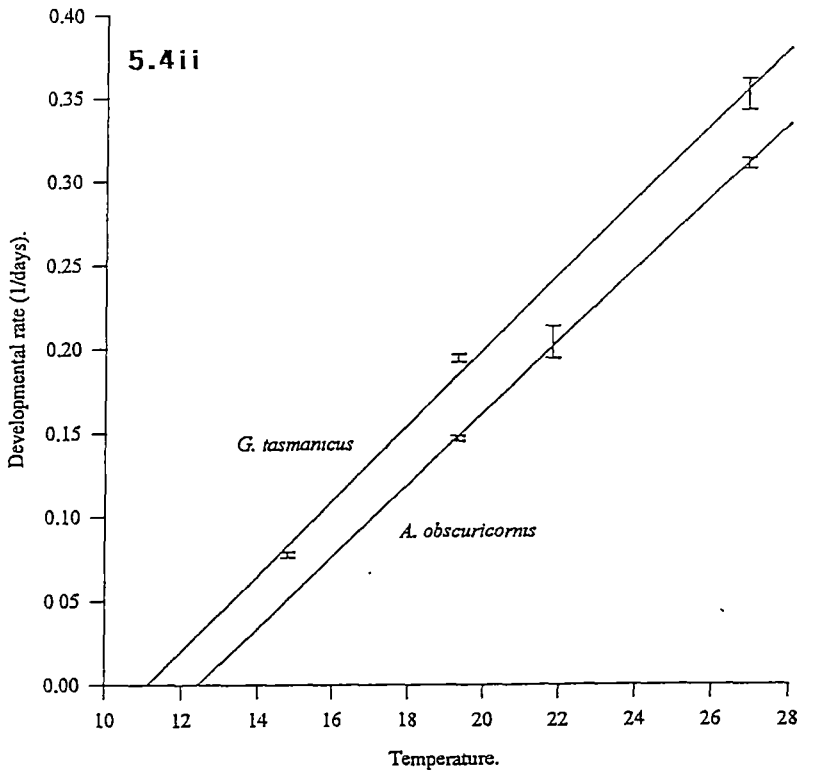
The inability to rear nymphs of *G. tasmanicus* to eclosion prevents comparison of the relative temperature preferences of the two species, as was undertaken for eggs. However, using developmental data for the ecdysis of first instar nymphs versus temperature some insights into the temperature preferences of each both species are possible. Using the data in Table 5.8 a straight line relationship was fitted to the points (Fig. 5.4ii). From these equations the number of degree-days and minimum developmental threshold temperature required for ecdysis in first instar nymphs of *A. obscuricornis* and *G. tasmanicus* was estimated as 12.4 and 11.1°C and 47 and 44 DD, respectively. These minimum developmental threshold temperatures are similar to those estimated for the eggs of each species, while the DD requirements for ecdysis of this instar are considerably lower than those of the respective species' eggs. The low DD requirements may reflect that the first instar is a comparatively shorter stage in the development of each species than that of the eggs. These findings suggest that *G. tasmanicus* nymphs may have the ability to develop and grow at lower ambient temperatures than *A. obscuricornis*.

Table 5.8. Developmental durations for nymphs of *Amorbus obscuricornis* and *Gelonus tasmanicus*. Results presented as means ± se. Durations measured in days. Ranges given in parentheses. First instar nymphs reared on excised shoots or potted eucalypts; second instar and older nymphs reared on potted eucalypts Percentage eclosion based on numbers of nymphs caged to potted eucalypts (see Chapter 2 for details).

Species, Temperature/photoperiod	I instar	II instar	III instar	IV instar	V instar	Total development time	% eclosing
A. obscuricornis							
32.0°C/24 hr light	2.5 ± 0.1 [n = 63] (2-4)	-	-	-	-	-	0 [n = 21]
27.0°C/16 hr light	3.2 ± 0.2 [n = 20] (1-4)	18.0 [n = 2] (17-19)	-	-	-	-	0 [n = 22]
26.9°C/24 hr light	3.31 ± 0.04 [n = 251] (2-5)	8.0 ± 0.4 [n = 6] (7-10)	6.5 ± 0.6 [n = 4] (5-8)	5.5 ± 1.2 [n = 4] (4-9)	11.3 ± 1.6 [n = 4] (9-16)	34.8 ± 3.1 [n = 4] (28-43)	8.7 [n = 46]
21.8°C/16 hr light	5.2 ± 0.2 [n = 33] (3-7)	18.9 ± 4.4 [n = 8] (10-46)	18.0 ± 8.5 [n = 3] (8-35)	-	-	-	0 [n = 39]
19.3°C/24 hr light	6.9 ± 0.1 [n = 98] (6-9)	17.7 ± 2.3 [n = 3] (14-22)	13.0 [n = 2] (12-14)	10 [n = 1]	20 [n = 1]	68 [n = 1]	2.9 [n = 35]
14.8°C/24 hr light	17# [n = 1]	-	-	-	-	-	0 [n = 8]
19.2-24.0°C/ambient light	5.2 ± 0.1 [n = 56] (4-7)	12.9 ± 1.1 [n = 14] (7-20)	9 4 ± 0.7 [n = 12] (6-14)	10.9 ± 2.0 [n = 9] (6-25)	19.6 ± 3.6 [n = 9] (10-46)	54.8 ± 4.8 [n = 8] (41-80)	15.3 [n = 59]
G. tasmanicus							
27.0°C/16 hr light	4.7 ± 0.4 [n = 7] (3-6)	13 [n = 1]	-	-	-	-	0 [n = 7]
26.9°C/24 hr light	2.9 ± 0.1 [n = 39] (2-4)	-	-	-	-	-	0 [n = 3]
19 3°C/24 hr light	5.2 ± 0.1 [n = 30] (5-6)	-	-	-	-	-	0 [n = 2]
14.8°C/24 hr light	13.0 ± 0.3 [n = 21] (11-15)	-	-	-	-	-	0 [n = 7]
19.2-24.0°C/ambient light	4.4 ± 0.1 [n = 28] (4-6)	11.4 ± 1.2 [n = 5] (8-15)	29 [n = 1]	-	-	-	0 [n = 28]

3 first instar nymphs held at 30°C for 1 d took 12.0 ± 0.6 d to ecdyse when exposed to 15°C.





Figs 5.4i, 5.4ii. Mean developmental rate versus temperature for: **(5.4i)** eclosion of *A. obscuricornis* ($y = - 0.0235 + 0.00197x$, $r^2 = 0.998$, N.B. data for 21.9°C collected at fluctuating temperatures); **(5.4ii)** ecdysis of first instar *G. tasmanicus* ($y = - 0.250 + 0.0225x$, $r^2 = 0.996$) and *A. obscuricornis* ($y = - 0.268 + 0.0215x$, $r^2 = 1.00$) nymphs.

5.3v. Adult Fat and Water Content Studies.

Fat analyses for 171 *A. obscuricornis* and 124 *G. tasmanicus* adults were undertaken from autumn 1992 to spring 1994. The results of these analyses are presented in Tables 5.9 and 5.10 and summarised in Figures 5.5 and 5.6. Fat content expressed on a percentage dry weight basis is presented in order to facilitate comparisons with other published works on this topic, for example Ito (1984, 1985). Figures 5.5 and 5.6 illustrate the seasonal changes in water and fat contents based on percentage live weight, however, because there is a closer relationship between these two parameters than for water content (% live weight) versus fat content (% dry weight) (see regression equations below).

A. obscuricornis (Table 5.9, Fig. 5.5). Average water contents of adult *A. obscuricornis* varied from 55.3 to 66.5%, while fat contents (% dry weight basis) ranged from 12.9 to 41.6%. As is apparent from these figures, water content is comparatively more constant than fat content irrespective of season. Despite this there was a high degree of variability in the estimates of both these parameters within any given season. The likely reasons for this variability are many and include differences in physiological age of insects, reproductive status, suitability of habitat, number of individuals utilised and time of collection. Generally, fat content (% live weight) was lowest during spring in adults of *A. obscuricornis*, which corresponded to the period of peak water content (% live weight) (Fig. 5.5). In contrast, fat content was highest during autumn and summer when water content was lowest.

An inverse relationship between percentage fat and percentage water was observed in adults of this species. Generally, those insects with high fat contents had lower water contents per mg of body weight. This relationship was most noticeable when fat content was correlated with water content per unit live weight ($y = 68.25 - 0.74x$, $r^2 = 0.51$). The correlation between fat content as a percentage of dry weight versus water content as a percentage of live weight was much reduced ($y = 67.76 - 0.28x$, $r^2 = 0.28$).

Table 5.9. Fat content analyses of *Amorbus obscuricornis* adults collected from autumn 1992 to spring 1994 from southern Tasmania. Data presented as means ± se where appropriate.

Season	Sex	n	Live weight (mg)	Water content (% live weight)	Fat content (% live weight)	Fat content (% dry weight)
Autumn '92	♂♂	2	87.5	63.4	12.8	34.4
Autumn '92	♀♀	5	117.7 ± 9.3	66.5 ± 2.9	12.1 ± 2.5	34.6 ± 5.2
Spring '92	♂♂	6	136.9 ± 9.0	64.3 ± 0.6	6.9 ± 0.8	19.3 ± 2.1
Spring '92	♀♀	6	193.0 ± 14.2	63.6 ± 0.7	8.5 ± 1.0	23.0 ± 2.5
Summer '93	♂♂	23	138.2 ± 6.5	61.8 ± 0.9	8.2 ± 0.8	20.9 ± 1.5
Summer '93	♀♀	19	174.7 ± 8.2	57.9 ± 1.9	16.0 ± 1.7	37.2 ± 2.8
Autumn '93	♂♂	20	134.5 ± 5.2	58.3 ± 0.6	9.9 ± 0.6	24.2 ± 1.7
Autumn '93	♀♀	22	154.7 ± 5.8	57.9 ± 1.0	9.2 ± 0.3	21.9 ± 0.6
Spring '93	♂♂	10	121.0 ± 9.5	64.3 ± 0.6	4.7 ± 0.5	12.9 ± 1.2
Spring '93	♀♀	12	153.4 ± 7.4	65.4 ± 0.8	6.2‡ ± 0.8	17.4‡ ± 2.0
Summer '94	♂♂	5	148.6 ± 6.5	60.8 ± 1.8	7.2 ± 1.3	18.1 ± 2.7
Summer '94	♀♀	10	164.8 ± 6.4	55.3 ± 1.7	14.9 ± 2.1	32.4 ± 3.3
Autumn '94	♂♂	6	170.3 ± 15.7	60.8 ± 2.3	14.9 ± 2.3	37.2 ± 4.6
Autumn '94	♀♀	10	181.7 ± 8.8	59.5 ± 3.4	17.7 ± 2.4	41.6 ± 3.2
Spring '94	♂♂	10	128.7 ± 7.3	65.2 ± 0.8	5.6 ± 0.4	16.0 ± 1.1
Spring '94	♀♀	10	155.5 ± 5.6	63.0 ± 0.9	6.4 ± 0.6	17.1 ± 1.3

‡ n = 11, one specimen destroyed during Soxhlet malfunction.

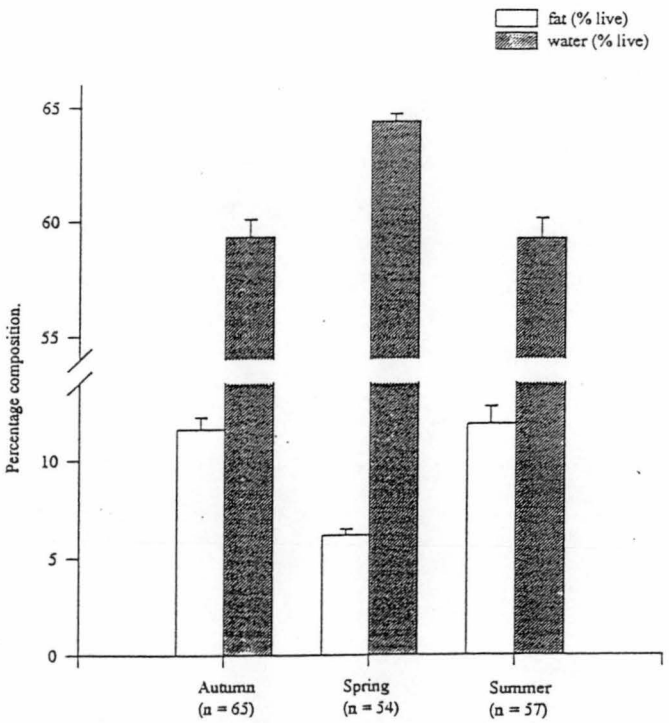


Fig. 5.5. Summary figure pertaining to Table 5.9 illustrating: (5.5) changes in fat and water contents (% live weight basis), respectively, of adult *A. obscuricornis* versus season.

G. tasmanicus (Table 5.10, Fig. 5.6). The trends observed for *A. obscuricornis* in relation to variability of fat and water contents were also apparent in adults of *G. tasmanicus*. The reasons for this variability would appear likely to be the same as those suggested for adults of *A. obscuricornis*. In this species fat content (% live weight) was also found to be lowest during spring, however, this period did not accord with peak water content which occurred during autumn and summer, in contrast to that for *A. obscuricornis*. This suggests that these two species may have different adaptive physiologies in relation to season.

As in *A. obscuricornis*, water content was inversely proportional to fat content in adults of *G. tasmanicus*. In this species also, water content per milligram of live weight was most closely correlated with fat content per unit live weight ($y = 68.09 - 0.62x$, $r^2 = 0.45$) in contrast to fat content per unit dry weight ($y = 67.19 - 0.20x$, $r^2 = 0.24$). The significance of body weight, water content and ambient relative humidity to the starvation longevity of adult coreids is considered in section 5.3viib.

Table 5.10. Fat content analyses of *Gelonus tasmanicus* adults collected from autumn 1992 to spring 1994 from southern Tasmania (unless otherwise stated). Data presented as means ± se where appropriate.

Season	Sex	n	Live weight (mg)	Water content (% live weight)	Fat content (% live weight)	Fat content (% dry weight)
Autumn '92	♀	1	59.6	57.9	17.8	42.2
Winter '92	♀♀	3	92.9 ± 10.2	59.5 ± 1.0	12.4 ± 0.9	30.5 ± 2.1
Spring '92	♂	1	43.4	66.1	5.8	17.0
Spring '92 (N Tas)	♀♀	4	64.5 ± 4.5	55.1 ± 3.7	14.9 ± 2.3	32.5 ± 3.2
Summer '93	♂♂	9	46.6 ± 2.0	59.6 ± 2.0	12.2 ± 1.6	29.4 ± 2.6
Summer '93	♀♀	3	87.4 ± 17.3	58.1 ± 7.6	12.4†	29.8†
Autumn '93	♂♂	10	39.5 ± 0.9	63.1 ± 1.2	12.5 ± 0.6	33.7 ± 1.1
Autumn '93	♀♀	10	61.3 ± 2.7	61.2 ± 1.8	13.6 ± 1.4	34.5 ± 2.4
Spring '93	♂♂	10	36.7 ± 1.4	63.2 ± 0.7	5.1 ± 0.5	13.9 ± 1.4
Spring '93	♀♀	16	72.0 ± 2.7	61.0 ± 0.8	7.4 ± 0.5	18.7 ± 1.1
Summer '94	♂♂	10	39.0 ± 1.1	64.7 ± 0.8	3.7 ± 0.6	10.5 ± 1.5
Summer '94	♀♀	10	71.2 ± 2.9	66.6 ± 0.4	2.9 ± 0.4	8.9 ± 1.2
Autumn '94	♂♂	10	38.5 ± 1.6	66.4 ± 1.8	10.1 ± 1.5	29.0 ± 3.6
Autumn '94	♀♀	7	52.3 ± 3.0	63.7 ± 2.0	12.3 ± 2.3	32.6 ± 5.2
Spring '94	♂♂	10	41.9 ± 2.0	65.5 ± 0.7	4.1 ± 0.4	11.8 ± 1.0
Spring '94	♀♀	10	84.0 ± 3.2	62.6 ± 1.0	6.8 ± 0.5	18.0 ± 1.1

† n = 2, one specimen destroyed during Soxhlet malfunction.

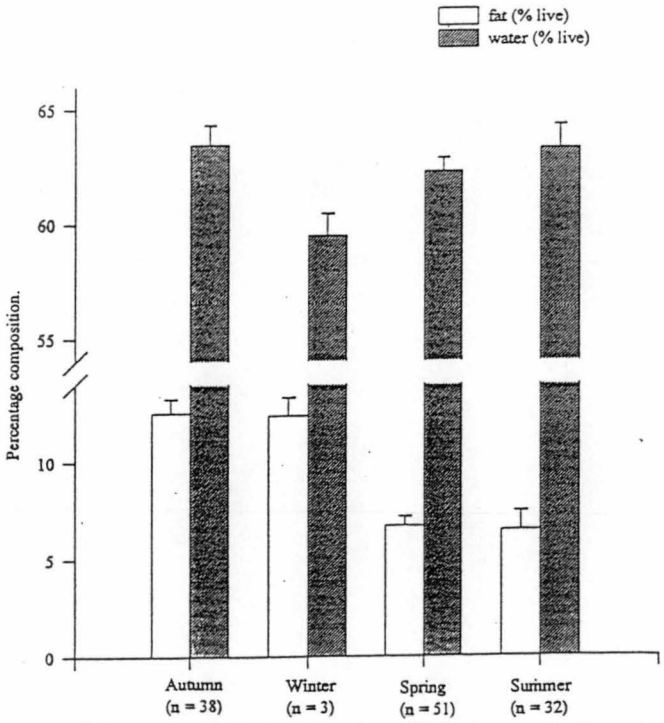


Fig. 5.6. Summary figure pertaining to Table 5.10 illustrating: (5.6) changes in fat and water contents (% live weight basis), respectively, of adult *G. tasmanicus* versus season.

5.3vi. Adult Starvation-Longevity Studies.

5.3via. The Influence of Temperature upon the Starvation-Longevity of Coreid Nymphs and Adults.

The starvation-longevities of *G. tasmanicus* and *A. obscuricornis* fifth instar nymphs and adults are presented in Table 5.11.

G. tasmanicus and *A. obscuricornis* nymphs. Of 17 nymphs, 2 *G. tasmanicus* and 1 *A. obscuricornis* eclosed during the experiment. Mean starvation-longevities for the two species at each temperature were not significantly different ($F_{1, 14} = 0.38$, $p = 0.550$ for *A. obscuricornis* and $F_{1, 6} = 0.61$, $p = 0.464$ for *G. tasmanicus*). In addition, there was no significant difference between starvation-longevities for male and female fifth instar *A. obscuricornis* nymphs ($F_{1, 14} = 0.89$, $p = 0.360$). That these data are not statistically significant may reflect the limited number of insects used, however, nymphs of *G. tasmanicus* appear to have longer starvation-longevities at low temperatures than *A. obscuricornis* (Table 5.11).

A. obscuricornis adults. Temperature has a very significant effect upon the starvation-longevity of adults of this species ($F_{3, 235} = 32.44$, $p < 0.001$). Mean starvation longevity is highest at 10.6°C and declines rapidly at temperatures above and below this point. The sex of an individual had no effect on starvation longevity ($F_{1, 235} = 0.73$, $p = 0.395$).

G. tasmanicus adults. The starvation-longevities for adults of *G. tasmanicus* were significantly affected by temperature ($F_{3, 115} = 15.15$, $p < 0.001$), however, there was no decrease in starvation-longevity at temperatures below 10.6°C as was apparent in *A. obscuricornis*. In contrast, starvation-longevity continued to increase as temperature decreased. Although females had longer average starvation-longevities than males, analysis of variance showed that the sex of an individual had no statistically significant affect upon starvation-longevity ($F_{1, 115} = 2.17$, $p = 0.144$).

Table 5.11. Mean starvation-longevities (in days ± se) of *Amorbus obscuricornis* and *Gelonus tasmanicus* nymphs and adults at 24 hr photoperiod and constant temperatures. Ranges given in parentheses. Number of individuals per treatment in [ ].

Species, Age/sex*	4.5°C	10.6°C	14.3°C	19.3°C
A. obscuricornis				
V instar ♂♂	62.2 ± 9.8 (23-72) [5]	59.4§ ± 20.1 (7-126) [5]	-	-
V instar ♀♀	61.3 ± 10.7 (40-72) [3]	86.0 ± 14.1 (53-122) [4]	-	-
adult ♂♂ [30]	49.3 ± 2.7 (15-73)	127.5 ± 13.0 (10-248)	85.3 ± 9.0 (4-180)	49.1 ± 5.6 (10-137)
adult ♀♀ [30]	45.3 ± 2.7 (11-90)	110.7 ± 15.2 (21-285)	88.5 ± 7.0 (14-171)	45.9 ± 4.5 (10-119)
G. tasmanicus				
V instar	96.0 ± 19.4 (54-129) [4]	76.8† ± 15.2 (45-107) [4]	-	-
adult ♂♂ [15]	100.1 ± 17.2 (41-241)	95.9 ± 14.6 (16-189)	46.1 ± 10.1 (5-121)	33.6 ± 6.5 (2-92)
adult ♀♀ [15]	170.7 ± 16.1 (22-372)	59.1 ± 13.3 (11-180)	69.5 ± 15.1 (6-177)	40.4 ± 8.6 (4-97)

* not possible to sex *G. tasmanicus* nymphs.
§ 1 nymph eclosed to an adult ♂ after 10 d and survived for 116 d.
† 1 nymph eclosed to an adult ♀ after 20 d and survived for 78 d, another eclosed to an adult ♀ after 36 d and survived for 71 d.

5.3vib. The Influence of Relative Humidity and Body Weight upon the Starvation-Longevity of Adult Coreids.

A summary of the results concerning adult starvation-longevity at different relative humidities (RH) is presented in Table 5.12. The data presented in these tables suggest that the effect of humidity on the starvation-longevity of *A. obscuricornis* adults is additive whilst for adults of *G. tasmanicus* it is not.

A. obscuricornis. Analysis of variance shows that humidity has a significant effect on the starvation-longevity of adults of this species ($F_{4, 109} = 44.78$, $p < 0.001$). Starvation-longevity was highest at 99 and 100% RH and lowest at 42, 63 and 79% RH. The sex of an individual had no significant effect ($F_{1, 109} = 0.78$, $p = 0.379$) upon starvation-longevity. These results are consistent regardless of whether longevity per individual is measured in days or days per mg of live weight. The significance of any effect due to sex on starvation-longevity is much reduced when the live weight of an insect is ignored and longevity is compared on a per unit weight basis.

G. tasmanicus. As in *A. obscuricornis*, the starvation-longevity of *G. tasmanicus* is also significantly influenced by relative humidity ($F_{4, 104} = 17.99$, $p < 0.001$). In this species, however, starvation-longevity was longest at 99% RH, followed by 100, then 63, 79 and 42% RH. Starvation-longevity was significantly affected by an individuals sex ($F_{1, 104} = 20.22$, $p < 0.001$). Females of *G. tasmanicus* had significantly greater starvation-longevities than males.

Of the two species used in this experiment the starvation-longevity of *G. tasmanicus* appears the most affected by live weight. Again relative humidity was found to significantly affect bug starvation-longevity when measured in days per mg of live weight ($F_{4, 104} = 23.66$, $p < 0.001$), with the trend the same as that mentioned previously. However, when the starvation longevity (measured in d mg^{-1}) of ♂♂ and ♀♀ was compared there was not found to be a difference in survival on a per unit weight basis ($F_{1, 83} = 2.63$, $p = 0.108$ for sex) in contrast to starvation longevity when measured in days per individual. Males were found to live only slightly less longer than females. This finding is readily interpreted when it is remembered that adult *G. tasmanicus* ♀♀ are considerably heavier than adult *G. tasmanicus* ♂♂ (see Table 5.10). In contrast, male *A. obscuricornis* are of a more similar live weight to female *A. obscuricornis*.

Table 5.12. Mean starvation longevities (in days per individual and days per mg) of *Amorbus obscuricornis* and *Gelonus tasmanicus* adults at 14.3°C, 24 hr photoperiod and constant relative humidities. Results presented as means ± se. Ranges given in parentheses.

Species, Sex [n/treatment]	42% RH		63% RH		79% RH		99% RH		100% RH	
	d	d mg^{-1}	d	d mg^{-1}	d	d mg^{-1}	d	d mg^{-1}	d	d mg^{-1}
A. obscuricornis										
♂♂ [10]	12.0 ± 2.5 (3-27)	0.091 ± 0.022 (0.018-0.255)	9.1 ± 1.3 (5-20)	0.089 ± 0.014 (0.040-0.197)	23.3 ± 5.4 (4-53)	0.157 ± 0.034 (0.052-0.375)	84.7 ± 12.3 (29-145)	0.594 ± 0.091 (0.321-1.176)	90.0 ± 13.8 (34-176)	0.635 ± 0.074 (0 286-0.931)
♀♀ [13]	16.6 ± 2.4 (4-33)	0.112 ± 0 017 (0.033-0.221)	12.4 ± 2.4 (4-37)	0.099 ± 0.019 (0 025-0.272)	31.0 ± 5 3 (8-59)	0.214 ± 0.038 (0 042-0.466)	76.2 ± 11.3 (11-180)	0.510 ± 0.069 (0.062-1.621)	107.0 ± 13.8 (30-188)	0.552 ± 0.058 (0 209-0.791)
G. tasmanicus										
♂♂ [12]	5.3 ± 0.7 (2-9)	0.139 ± 0.017 (0.053-0.251)	11.3 ± 1.0 (7-15)	0.282 ± 0.025 (0.177-0.422)	8 8 ± 1.2 (4-17)	0.229 ± 0.029 (0.103-0.419)	21.3 ± 3.1 (5-40)	0.553 ± 0.079 (0.145-1.130)	25.8 ± 5.0 (5-54)	0.658 ± 0.121 (0.145-1.413)
♀♀ [10]	10.0 ± 1.7 (2-18)	0 156 ± 0.022 (0.036-0.251)	13.1 ± 2.1 (7-27)	0.224 ± 0.026 (0.146-0.393)	15.1 ± 3.1 (4-34)	0.268 ± 0.048 (0.076-0.579)	68.4 ± 11.3 (19-114)	1.019 ± 0.154 (0.403-1.621)	38.6 ± 6.8 (8-68)	0.600 ± 0.084 (0.174-1.016)

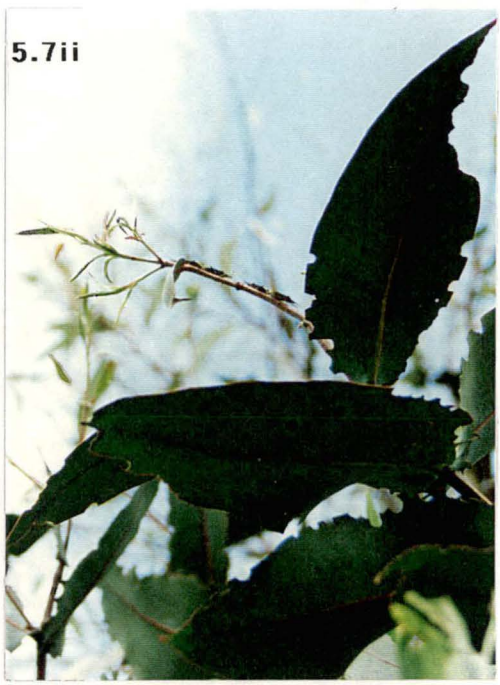
5.3vii. Seasonality of Copulatory Behaviour and Fecundity in Coreids.

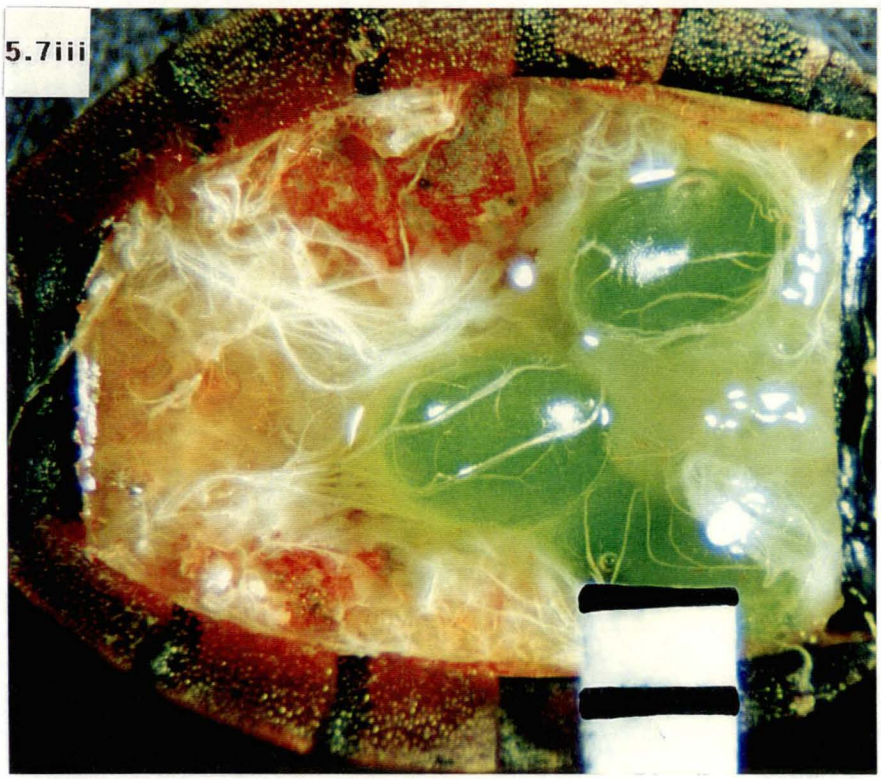
Copulating adults of *A. obscuricornis* were found throughout spring and summer with the majority occuring during mid to late spring and early summer. Copulating pairs generally represented less than 24% of the total of either sex collected during spring and summer (Table 5.13). During the period when most females are *in copula* the proportion of males to females collected is also male biased. It was observed that during the months of autumn, when copulatory behaviour has ceased, the proportion of males to females collected is often slightly female biased. Spring also corresponds to the period when most adult females are gravid. During this period all females dissected were found to have ovaries containing eggs (Fig. 5.7iii). The number of gravid females declines during summer.

The timing of reproductive activity in adults of *G. tasmanicus* (Fig. 5.7i) appears very similar to that recorded in *A. obscuricornis*. For example, Table 5.13 shows that most copulatory activity occurs during spring and summer. On warm sunny days in spring numerous large aggregations, consisting almost entirely of copulating pairs and solitary males, can occasionally be seen in plantations of *Eucalyptus nitens* (Fig. 5.7ii), however, the appearance of these aggregations is very brief. Following the disappearance of these aggregations copulating pairs become more inconspicuous. In this species the period of copulation appears slightly more extended, as rates of copulation were recorded to remain relatively high until mid summer. In this species also, the period of greatest copulatory behaviour corresponds to times when the proportion of males to females is notably male biased. In addition, maximum copulatory behaviour coincides with the period when most females are gravid. In general, percentage of copulating pairs in collections were considerably higher (often 2 to 3 times) in adult *G. tasmanicus* than *A. obscuricornis* (Table 5.13).

Table 5.13. Ratios of males to females, percentage of copulating pairs and gravid females in collections of *Amorbus obscuricornis* and *Gelonus tasmanicus* by season. Number of females dissected for fat analyses given in [ ]. Months in which no dissections were undertaken are indicated by a "-". Results represent cumulative observations made from autumn 1992 to spring 1995.

Species/month	Season	n	Proportion ♂♂ : ♀♀	% ♀♀ *in copula*	% gravid ♀♀	Eggs per gravid ♀ ± se
A. obscuricornis						
Mar.	autumn	331	0.6 : 1	0	0 [n = 32]	0
Apr.		249	0.9 : 1	0	0 [n = 2]	0
May		8	0.3 : 1	0	0 [n = 3]	0
Sep.	spring	87	2.6 : 1	4.2	-	-
Oct.		193	1.3 : 1	15.7	100 [n = 16]	6.0 ± 0.5
Nov.		277	1.1 : 1	20.8	100 [n = 12]	4.1 ± 0.7
Dec.	summer	262	1.7 : 1	23.7	-	-
Jan.		91	1.1 : 1	7.0	40.0 [n = 20]	2.0 ± 0.7
Feb.		96	1.7 : 1	6.1	0 [n = 9]	0
G. tasmanicus						
Mar.	autumn	118	0 9 : 1	0	0 [n = 1]	0
Apr.		113	1.2 : 1	0	0 [n = 16]	0
May		12	2.0 : 1	0	0 [n = 1]	0
Jun.	winter	-	-	-	0 [n = 2]	0
Aug.		-	-	-	0 [n = 1]	0
Sep.	spring	208	1.1 : 1	62.9	71.4 [n = 14]	2 4 ± 0.5
Oct.		295	1.9 : 1	61.4	100 [n = 10]	3.8 ± 0.4
Nov.		295	1.7 : 1	58.3	100 [n = 16]	4.8 ± 0.8
Dec.	summer	306	1.4 : 1	78.7	-	-
Jan.		43	2.1 : 1	21.4	58.3 [n = 12]	1.2 ± 0.4
Feb.		35	1.7 : 1	7 7	0 [n = 1]	0





Figs 5.7i-5.7iii. Photographs of: **(5.7i)** copulating pair of *G. tasmanicus*, ♀ (top) feeding; **(5.7ii)** two of the often numerous pairs of *G. tasmanicus* which can be seen on warm spring days; **(5.7iii)** a dissected *A. obscuricornis* ♀ with 3 eggs at an advanced stage of development and relatively little fat (scale line interval = 1 mm).

5.4. *Discussion*

5.4i. Egg Development Studies.

Using observations of time to hatching versus temperature, linear models for *A. obscuricornis* and *G. tasmanicus* egg development are presented. The results of this work suggest that of the two species, eggs of *G. tasmanicus* may be better adapted to colder temperatures than those of *A. obscuricornis*. Evidence for this is provided by a lower minimum developmental threshold temperature and the ability of eggs of this species to develop and hatch given fewer DD.

Photoperiod was found to have a small, but significant, effect on the development of eggs of both species. Results for eggs of *A. obscuricornis* suggested that extremes of humidity may influence egg developmental rate and viability. Given that these two species are terrestrial, as opposed to aquatic, it is not surprising that humidity may only have a small effect upon the development and viability of their eggs (Cobben 1968).

5.4ii. Nymphal Development Studies.

Development of nymphs of *A. obscuricornis* and *G. tasmanicus* proceeds via five instars. This finding contradicts Green (1972) and Bashford (1992 *in lit.*) who reported that *A. obscuricornis* had six nymphal instars.

The results presented in section 5.3iii suggest that first instar nymphs of *A. obscuricornis* probe their host eucalypt, not to ingest carbohydrates, but rather to imbibe water. The moisture thus imbibed serves to prevent the nymph from dessicating and appears integral to ecdysis.

Estimations of Przibram's (1912, in Torre-Bueno 1989) progression of growth factors for *A. obscuricornis* and *G. tasmanicus* nymphs approximated theoretically predicted values. Kumar (1966) estimated growth factor values of 1.22 for nymphs of *Amorbus rubiginosus* and *A. alternatus*, which were similar to the values obtained in this study. Enders (1976) reported that such growth constants were positively correlated with the size of the species and the number of instars. This statement appears to be partly supported by these findings given that *A. obscuricornis* is considerably larger than *G. tasmanicus*. Enders considered that lower growth constants inferred mechanical advantages on the insects in question by reducing power to weight ratios, thus increasing agility. Dingle *et al.* (1980) demonstrated that body size is frequently influenced by proximate environmental conditions such as food availability, which may explain differences between estimated

growth constants for similarly sized species such as *A. obscuricornis* and *A. rubiginosus*.

Despite the hatching of many eggs of both species, few nymphs of *A. obscuricornis* and no *G. tasmanicus* were reared through to eclosion under controlled conditions. Thus, only scant data can be presented concerning the temperature requirements of nymphs.

5.4iii. Adult Development and Biology Studies.

Analyses of adult coreids revealed that fat was accumulated prior to the onset of unfavourable conditions. As expected, water content was generally found to be inversely proportional to fat content (Wharton 1985). The high fat contents of overwintering adults are considered to act as fuel reserves.

The starvation-longevity of adults of both *A. obscuricornis* and *G. tasmanicus* was found to be significantly influenced by temperature. These findings suggest that of the two species *G. tasmanicus* may be better adapted to starvation at low temperatures. This also shows that adults of these two species have the ability to survive part of autumn and all of winter without feeding. In addition to temperature, relative humidity and an insect's body weight were found to have a significant bearing upon an individual's starvation-longevity.

Observations of seasonal copulatory behaviour demonstrated that adults of both *A. obscuricornis* and *G. tasmanicus* commence mating almost immediately following their spring emergence, perhaps after a short period of feeding. It is possible that the adults observed copulating during mid to late summer may be newly eclosed adults which are about to overwinter. The timing of mating and peak female egg load appear closely linked.

5.4iv. Significance of Coreid Biology to Their Biogeography and Host Plant Utilisation.

Many of these aspects of the biology of *A. obscuricornis* and *G. tasmanicus* would appear to have important significance to the biogeography and host plant utilisation strategies of each species. For example, the ability of eggs of *G. tasmanicus* to develop at lower temperatures than those of *A. obscuricornis* may partly explain this species' presence in high altitude regions of Tasmania and the Australian mainland (see Chapter 4 and Morrow 1977b). Similarly, given that *A. obscuricornis* is the only *Amorbus* species found in Tasmania, it seems likely that the developmental threshold temperature and

number of DD this species requires for egg, and possibly also nymphal growth, are likely to be lower than those of mainland species, particularly those with more northerly distributions. Should such an hypothesis be found to be correct it might partly explain why mainland species did not colonise Tasmania during periods when the two land masses were connected (see discussion section of Chapter 4).

The findings reported in this chapter also have important implications for the host plant utilisation strategies of both species which will be considered further in Chapters 6 and 7. For example, results from the morphometric study found that both species exhibit low growth increments (i.e. Przibram's progression factors) between each moult. In addition to differences in magnitude of increment resulting from the size of an insect, Enders (1976) also related low increments of size increase in true bugs to the fact that such insects must "move about the environment to feed only at particular spots". Such a finding may have particular relevance to *A. obscuricornis*, given that nymphs of this species need to locate a new shoot each time the present host becomes severely wilted. That is, nymphs cannot remain on the one stem in order to complete their development and may need to search the host plant for other suitable shoots or leave the host in order to locate another.

Nymphal development studies indicated that the commencement of feeding is not a simple process and that it's successful initiation may be an important factor in the insect-plant relationships of these species. There are a number of possible causes for the high mortality rates of coreid nymphs reared under artificial conditions. For example, poor growth of potted eucalypts under artificial conditions was suspected as being one of the main causes for rearing failures. Cathey and Campbell (1980) reported that stem elongation in plants exposed to illumination from cool white fluorescent and high intensity discharge mercury vapour lamps, as per the artificial rearing conditions, was slow. Maelzer (1981) reported that the growth of populations of the aphid, *Toxoptera citricidus* (Kirk.), was greatest when citrus shoots were elongating rapidly and that aphid numbers declined in response to reduced shoot growth. A similar relationship between shoot extension and the population growth of *Macrosiphum rosae* (L.) was also observed by Maelzer (1977). These papers show that slow stem elongation is not beneficial to the growth of shoot feeding insects such as *A. obscuricornis*. Changes in plant physiology under artificial conditions may also have influenced the initiation of nymphal feeding. For example, the shutting of stomata at elevated temperatures may have reduced the ability of second instars to penetrate the stem to initiate feeding (Parry 1971; Bing *et al.* 1991;

Mensah and Madden 1992).

Fat and water content analyses support earlier work from Chapter 4 which suggested that both species were univoltine in Tasmania and that adults were the overwintering stage. Although adults may not feed during the winter, the availability of moisture is a crucial factor influencing their survival. This result, together with observations of experimental adults "drinking" droplets of water, indicate that in order to avoid dehydration adults imbibe water during overwintering.

It was observed that peak rates of copulation also corresponded to periods when the proportion of males to females was noticeably male biased. Such an imbalance would enhance the possibility of females finding a mate and being fertilised prior to oviposition. Amongst many Heteroptera it appears that males attract females through the emission of volatile pheromones (Borges *et al.* 1987 and references therein). For example, male *Leptoglossus phyllopus* (L.) have been shown to be responsible for attracting females through the use of pheromones (Aldrich *et al.* 1976). Similarly, the large migratory swarms of male *Thasus acutangulus* (Coreidae) observed by Torre-Bueno (1945) were considered further evidence that male Heteroptera are the initial colonisers and emitters of pheromones which attract migratory females (Aldrich and Blum 1978). Mating aggregations have also been recorded in *Acanthocephala femorata* (F.) (Coreidae) (Mitchell 1980b) and *Nezara viridula* (L.) (Pentatomidae) (Clarke and Walter 1993). The large number of sensilla on the distal antennal segments of some Heteroptera are considered the olfactory receptors for these pheromones (Levinson *et al.* 1974; Harbach and Larsen 1976). Some of the chemosensory structures observed on the distal antennal segments of *A. obscuricornis* (Figs 3.37i-3.37iv) may function in this capacity. Such behaviour may play an important role in the host plant selection (Chapter 7) and overall ecology of these bugs. For example, Aldrich *et al.* (1976) hypothesised that males were the colonisers of new habitats and that by attracting females into favourable host patches, energy expenditure on the part of female insects would be minimised. A similar phenomenon may occur in *A. obscuricornis* and *G. tasmanicus*, i.e. a favourable host plant stand might attract many colonising males who in turn release large quantities of sex pheromone and thereby attract a large number of females. It could be postulated that the abundance of nymphs within a given season is correlated with the mating success of parental insects, i.e. large populations of immatures may only be seen when the number of males in a particular habitat is very high leading to the attraction of many females.

Chapter 6

Host Plant Performance of *Amorbus obscuricornis* and *Gelonus tasmanicus* on Selected *Eucalyptus* Species

Chapter 6

Host Plant Performance of *Amorbus obscuricornis* and *Gelonus tasmanicus* on Selected *Eucalyptus* Species

6.1. *Introduction*

6.1i. Host Plant Performance of Herbivorous Insects.

Host plant performance is a measure of the quality of a herbivore's host plant to facilitate the growth, survival and reproduction of that herbivore's offspring following oviposition (Thompson 1988; Craig *et al.* 1989; Horner and Abrahamson 1992; Kouki 1993; Calatayud *et al.* 1994). The oviposition preferences of adult females are thought to be under evolutionary selection so as to maximise the performance of their offspring (Jaenike 1978; Ruiz and Heed 1988; Craig *et al.* 1989; Kouki 1993). The rationale behind this thinking is that immatures are often less mobile than their parents and must therefore develop at or near the oviposition site, as they are not readily able to migrate to a more favourable site if this is required (Jaenike 1978). Craig *et al.* (1989) found this prediction to be especially relevant to insects which develop directly at the oviposition site, for example sawfly larvae. That this rationale does not apply to the ovipositional behaviour of all female herbivores can be seen in the works of Valladares and Lawton (1991) and Horner and Abrahamson (1992). Comprehensive discussions of this subject can be found in Thompson (1988) and Courtney and Kibota (1989).

Horner and Abrahamson (1992) extended host plant performance beyond immature insect herbivores to include the "feeding individual". Thus, this concept may include adult insects, particularly those with limited migratory abilities and/or a narrow range of available host plants.

The host plant performance of immature and adult insects on particular plants has been used as an indicator of a species host plant specificity (McFadyen 1983, 1987; Cullen 1989; McFadyen and Marohasy 1990). However, Morrow (1977b), in a study of eucalypt herbivores, defined host specificity simply in terms of the relative abundance of an insect species across a range of potential host plants. She arbitrarily defined host specific species were those in which 80% or more of individuals collected in a sample derived from one host species. This author's definition made no assumptions concerning the basis of the host preferences and did not exclude the possibility that an insect may feed upon other hosts under different situations.

The use of no-choice or starvation tests, where a plant's suitability as a host is measured in terms of the insect's host plant performance, are commonly used in host plant specificity screening of potential weed biological control agents (Cullen 1989). The apparent host range of such agents, which it should be remembered are initially selected because of suspected monophagy or narrow oligophagy, has typically been found to become increasingly narrow under no-choice, choice and field situations, respectively (McClay 1995 *in lit.*). No-choice and choice testing to determine a specie's host specificity are considered essential means of screening biological control agents, however, it must be remembered that development of an insect on a given plant under such circumstances measures that agents "physiological host range" and that in nature additional behavioural and ecological factors influence the agent's actual host range (Cullen 1989).

It is the intention of the work presented here to gain some insights into the apparent host plant specificity of *A. obscuricornis* and *G. tasmanicus* on selected eucalypts when given no-choice. To this end the immature and adult host plant performance of each species was measured to infer possible differences in host specificity. In the next chapter the factors important in host plant selection in the field will be considered.

6.1ii. The Factors Influencing Host Plant Performance of Herbivorous Insects in No-Choice Experiments.

In glasshouse conducted no-choice experiments, the effect of environmental factors such as spatial and temporal coincidence of plant species can be reduced, allowing clearer resolution of the significance of chemical and tactile stimuli in the host specificity of an insect (Cullen 1989). In other words, because plant "findability" is increased to 100% in no-choice experiments, the role of host "suitability" can be examined in relation to an insect's host specificity without being confounded by behavioural or ecological influences (Ruiz and Heed 1988; Cullen 1989). Ruiz and Heed (1988) considered that a plant's suitability was determined by it's chemical and physical characteristics. Amongst these characteristics were included the plant's water and nitrogen contents and the variety of secondary compounds. In addition to these characterisitics, Jaenike (1978) considered that a host's suitability also encompassed microhabitat and degree of infestation, which become important under field conditions. Host plant suitability not only varies between plant species, but also within species and it is this variation which is thought to determine an insect's degree of host specificity (Jaenike 1978).

There is little literature available concerning the chemical and physical plant characterisitics that influence host specificity in Coreidae. Morrow (1977b) found large numbers of *G. tasmanicus* on *E. perriniana* and *E. pauciflora* at a field site in New South Wales, suggesting that the species was oligophagous for these eucalypts. To-date, most host specificity studies using Hemiptera have concentrated upon aphids (which are almost completely absent from eucalypts (Ohmart and Edwards 1991) and, to a lesser extent, leafhoppers. As a result of the paucity of host specificity studies specific to Coriedae the following discussion will focus on the factors which influence host specificity in sucking insects (Hemiptera) in general. The factors which influence host specificity in chewing insects will not be considered, unless they illustrate some unifying concept. The assumption behind this neglect of the chewing insects is that the pronounced feeding selectivity of sucking insects may enable them to largely bypass plant defenses, thereby allowing host plant specificity to be regulated by completely different factors (Schaefer and Mitchell 1983).

Two significant points need to be remembered when comparing the chemical and physical factors which influence the host specificity of aphids/psyllids (in particular) and coreids. Firstly, coreids have a different mode of feeding to that of aphids. Coreids feed from parenchyma in and around vascular tissues using the "osmotic pump" mechanism described by Miles and Taylor (1994). This mechanism differs not only to that of aphids, but also to that found in other Heteroptera, such as Lygaeidae, Pentatomidae and Miridae. The osmotic pump mechanism utilises a salivary sucrase to increase the osmotic concentration of intercellular fluids, thereby inducing phloem unloading. The cells of the parenchyma shrink and their contents are then withdrawn from the apoplast. The osmotic pump mechanism also increases the quantity of amino acids released from nearby tissues for uptake (Miles and Taylor 1994). In contrast, aphids and psyllids withdraw plant sap directly from phloem sieve tubes (Clark 1963; Miles and Taylor 1994).

Secondly, within the Coreidae, feeding is not restricted simply to sap as it is in aphids and psyllids. For example, some species feed primarily on vegetative tissues (shoots, petioles and foliage) whilst others attack reproductive organs (seeds and fruits) (Schaefer and Mitchell 1983), and these differences may affect host plant performance. Mitchell (1980a) found that *Leptoglossus phyllopus* (L.) (Coreidae) fed upon developing seeds in generative structures and that moisture was obtained by probing xylem elements in vegetative plant parts. Immature seeds are thought to be protected by the developing fruit and thus comparatively devoid of toxins (references in Mitchell 1980a). Ehrlich and

Murphy (1988) inferred this to mean that *L. phyllopus* was able to avoid plant toxins by feeding on immature seeds. Extension of this argument would imply that coreids which feed from the vascular tissues of vegetative plant parts are likely to encounter secondary metabolites and/or their precursors. That certain types of secondary compounds circulate in phloem sap is demonstrated by the work of Calatayud *et al.* (1994). These authors suggested that changes in the phloem concentrations of rutin (an unfavourable compound) and cyanide (a phagostimulant) could be partially responsible for population fluctuations of *Phenacoccus manihoti* (Matile-Ferrero) (Pseudococcidae). Waterhouse *et al.* (1961), also speculated that species of *Amorbus* obtained the *n*-hexanal component of their defensive secretions from the sap of eucalypt host plants. Thus, the host plant performance of exclusively sap feeding corieds may be influenced by different factors to that of seed feeding coreids.

6.1iia. Effect of Nitrogen on the Host Plant Performance of Sucking Insects.

Nitrogen is generally regarded as an extremely important nutrient in insect-plant interactions (see Mattson 1980; Schowalter *et al.* 1986 and references therein). Kennedy and Booth (1951) found that aphids discriminated between leaves of the same host species on the basis of age, feeding preferentially and reproducing more rapidly on young and early senescent leaves in comparison to mature leaves. These differences were related to changes in the concentration of amino acids, which were highest in young and early senescent leaves (favouring high fecundity), while lowest in mature leaves (reducing fecundity) (Kennedy and Booth 1951). In contrast to Fraenkel (1959) (see section 6.1iib), these authors suggested that nutritional (primary) substances could act to stimulate feeding and other behaviour (Kennedy 1958). Moreover, Kennedy and Booth (1951) also found that the readiness of aphids to settle, feed and reproduce was influenced by the kind of leaf. They proposed that aphids not only responded to universal substances such as amino acids but also to substances of no nutritive value, i.e. secondary substances, when selecting a host. This hypothesis was termed the "dual discrimination theory" of host selection and it was considered that this theory helped explain the phenomenon of host plant alternation in which aphids utilise botanically dissimilar hosts. The work of van Emden (1972, 1978), Kidd (1985) and Kidd *et al.* (1990) support the proposition that the interactions of nutritional and allelochemic factors significantly influence the host plant selection of aphids.

Further to Kennedy and Booth's pioneering work, van Emden and Bashford (1971) illustrated that the growth of the aphids *Myzus persicae* (Sulz.) and *Brevicoryne brassicae*

(L.) on brussel sprouts was poorly correlated with total soluble nitrogen, but was better explained by a few constitutive amino acids. It was shown that both aphid species responded positively to asparagine and glutamine and that additional amino acids were of different relative significance (positive or negative) to each species. The importance of specific amino acids to aphid feeding was also shown by Mittler (1970). Miles *et al.* (1982a, b) illustrated that the amino acid content of foliage could be altered by water stress. In particular, the amino acid proline was found to increase in concentration with droughting. In *E. camaldulensis*, water stress was associated with an increase in total nitrogen, and proline, and a decrease in phenolics in comparison to well watered plants (Miles *et al.* 1982a).

The importance of nitrogen and amino acids to the host plant performance and specificity of sucking insects other than aphids has been demonstrated by a number of authors (see Prestidge and McNeill 1983; Brodbeck *et al.* 1990; Thompson 1994). Thompson (1994) found that some species of spittlebug (Cercopidae) attain higher population densities on nitrogen-fixing plants than on non leguminous species. Given that these insects feed from the xylem it is suggested that their fecundity may be enhanced on plants with high nitrogen contents, namely nitrogen-fixing legumes. In reviewing the literature pertaining to the effect of various factors on the rate of eucalypt herbivory, Ohmart and Edwards (1991) concluded that the growth of insect defoliators was most affected by the nitrogen content of foliage.

6.1iib. Plant Secondary Compounds and Their Effect on Host Plant Performance of Sucking Insects.

Fraenkel (1959) first suggested that secondary plant substances determined the food specificity of insects. Fraenkel argued that because the basic food requirements of all higher animals were predominantly alike, and given that plants were of similar nutritional quality, insect selection must not be determined by primary substances. Rather, it was argued that variations in secondary substances were responsible for food specificity (Fraenkel 1959). These secondary substances were considered to include those non-nutritional elements (i.e. the primary substances) which vary in occurrence depending upon plant group, for example phenols, glucosides, saponins, tannins, alkaloids, essential oils and organic acids. Moreover, the concentrations of secondary compounds within individual plants may fluctuate in response to herbivory; where such changes have reduced herbivore feeding they have been termed "induced defenses" (Haukioja 1990). According to Ohmart and Edwards (1991), the presence of induced defenses in eucalypts

had not been demonstrated at the time their review was written. Haukioja (1990) provides a recent review of induced defenses. Because eucalypts possess such a diverse allelochemistry (Ohmart and Edwards 1991), any study of insect host specificity on such plants which did not consider the significance of these compounds would not be complete.

Eucalypts are characterised by many of the above compounds, however, the genus is particularly noted for it's high content of essential oils (Welch 1920; Carr and Carr 1969; Boland *et al.* 1991; Li 1993). Although oil glands are commonly associated with mesophyll cells in the leaves (Boland *et al.* 1991) they also occur in petioles, young stems, calyx, operculum and fruits (Welch 1920). In addition, some 42% of studied species also have oil glands in the pith or the phloem (Carr and Carr 1969). Despite this high concentration of oil glands and other secondary metabolites, and the importance of these compounds in other non-eucalypt insect-plant interactions, studies to-date have found that these constituents have relatively little effect on the levels of herbivory and larval performance of the insects investigated (Ohmart and Edwards 1991). Morrow and Fox (1980) hypothesised that a threshold essential oil content may need to be surpassed before insect herbivory is affected. Recently, Stone and Bacon (1994) found that some *E. camaldulensis* which had high cineole contents suffered less herbivory than trees with low oil contents. These authors considered that such trees had oil contents above this threshold level. Similarly, Li (1993) postulated that the low cineole content of *E. nitens* foliage significantly increased its susceptibility to attack by *Chrysophtharta bimaculata* (Olivier) (Chrysomelidae). It should be noted that these studies were performed using chewing (e.g. Fox and Macauley 1977; Morrow and Fox 1980; Li 1993) rather than sucking insects.

The dual discrimination theory of host selection (see section 6.1iia) (Kennedy and Booth 1951) emphasises the importance of both primary and secondary plant substances in host selection by aphids. Kennedy (1958) considered that aphids exhibited "nutritional" selection in relation to primary substances and "botanical" selection in response to secondary substances. The role of secondary plant substances in the performance of aphids would seem particularly well illustrated by the work of Kidd (1985) and Kidd *et al.* (1990), using the aphids, *Cinara pinea* (Mordv.), *C. pini* (L.) and *Schizolachnus pineti* (Fabr.), which are host specific for Scots pine (*Pinus sylvestris* L.). Kidd (1985) suggested that the performance of *C. pinea* on Scots pine (which has a diverse allelochemistry) might not be explained solely on the basis of the quality and quantity of

amino nitrogen. It was suggested that the presence of allelochemics, specifically total phenols, "may promote growth and fecundity by acting as phagostimulants, or reduce growth and survival by a repellent effect or by interfering with digestion." Subsequent studies by Kidd *et al.* (1990) have confirmed the importance of non-nutritive substances on the suitability of individual Scots pine for aphid feeding. For example, when shoot extension of Scots pine was most rapid there was a marked increase in the numbers of *C. pini* on the current season's growth. During these months, tissue amino acid concentrations were high whilst phenolic and terpene compounds were down on levels found in mature growth. The numbers of *C. pini* on the current season's growth steadily fell as shoots matured and amino acid concentrations declined whilst phenolic compounds doubled.

Aphid feeding may also induce changes in the concentration of secondary compounds. Kidd *et al.* (1990) showed that the feeding activities of *S. pineti* and *C. pini* increased the number of phenolic compounds in Scots pine, while Miles (1985) suggested that the feeding activity of *Macrosiphum rosae* (L.) might influence the release of catechin, thereby providing a possible explanation for the departure of aphids from their host plants during certain plant growth stages. Later studies confirmed this hypothesis (Peng and Miles 1988). Campbell *et al.* (1986) found that the ability of aphids to hydrolyse cell wall polysaccharides, thereby producing oligosaccharides with phagostimulant properties, influenced their behavioural response to natural host plants.

Studies of *Cardiaspina albitextura* Taylor (Psyllidae) and its natural host plant, *Eucalyptus blakelyi*, have found that increasing concentrations of phenolic compounds exert an adverse affect on the survival of first instar nymphs (Morgan 1984). Interestingly, the feeding activity of this psyllid can increase foliar concentrations of nitrogen and phenolics (Morgan 1984). Moore (1988) detailed the host specificity of eucalypt feeding psyllids belonging to the genus *Glycaspis* Taylor (Spondyliaspididae) and reported that some species were host-specific, whilst others were specific for a number of eucalypt species belonging to the same series. Details concerning possible factors influencing host specificity were not provided.

6.1iic. Other Factors Influencing Host Plant Performance of Sucking Insects.

Schowalter *et al.* (1986) grouped the physical properties of plants which influence their suitability to insects into those which make foliage slippery (e.g. waxes), increase toughness (e.g. cellulose and lignins), reduce palatability physically (e.g. silica and

oxalate crystals), interfer with feeding by being sticky and/or toxic (e.g. gums and resins) or act as physical barriers (e.g. trichomes). Ohmart and Edwards (1991) reported that leaf toughness and surface waxes exert an influence on insect herbivores of eucalypts which varies according to the species concerned.

No studies appear to have addressed the effect of leaf toughness or surface waxes upon the feeding activities of sucking insects, however, a number of works have considered these factors in relation to chewing insects. Lowman and Box (1983) found that, in general, toughness and chemical toxicity of leaves increased with age. These changes were accompanied by a fall in insect herbivory which was more positively correlated with toughness than with phenolic compounds. Edwards (1982) found that adults of the leaf beetle, *Paropsis charybdis* Stål (Chrysomelidae), could not grip the waxy juvenile foliage of "bluegum" eucalypt species and suggested that this may confer some resistance to the trees. Similar findings have also been reported by Edwards and Wanjura (1990).

6.2. *Materials and Methods*

6.2i. No-Choice Host Plant Performance Experiments.

The aim of these experiments was to investigate whether adult and nymphal performance differed according to eucalypt species. Insect performance on as many of the endemic Tasmanian eucalypts as could be obtained (in addition to the introduced plantation species, *Eucalyptus nitens*) was attempted. The measures of insect performance which were employed included:

- the longevity of adult insects
- the numbers of eggs laid by adult females
- the survival rate of nymphs
- the weight of eclosed adults

Oviposition rate was estimated relative to the weight of adult females. These studies were conducted during spring, summer and autumn of 1992/93, 1993/94 and 1994/95. The number of replicates, species of eucalypts and other details varied slightly in each year, however, the basic design of these no-choice host plant performance experiments can be summarised as follows.

• Eucalypts. Trees were less than two years old at the start of each experiment and were grown as per the details given in Chapter 2. Generally, two potted eucalypts were kept in each cage. At the start of each experiment every eucalypt was given an amount of Osmocote® slow release fertiliser (formula for outdoor, trees and shrubs). This quantity of fertiliser was adequate for the needs of the plants over the duration of the experiment (according to the manufacturers specifications). Trees were pruned at approximately monthly intervals to promote shoot formation and prevent cage closure due to excessive growth. Each tree was given 150 ml of water per day, unless the soil appeared waterlogged. Trees which died during the experiment were replaced with ones of the same species and age.

• Insects. Adult *A. obscuricornis* and *G. tasmanicus* were collected from field locations as early in the season as numbers permitted. Insects were collected only a few days prior to commencing these experiments. Insects were generally collected from the same location and at the same time. As insufficient insects could be reared under glasshouse conditions for use in these experiments it was hoped that by collecting insects at the same time and from the one location it would be possible to minimise differences in bug age and history. Prior to their use in the experiment each bug was anaesthetised, weighed to 0.1 mg and given an identifying label (see Chapter 2).

A pair of insects was released into each cage containing potted eucalypts. Insects that failed to become established on particular eucalypts and died without ovipositing, or died within seven days of being placed into a cage, were replaced with weighed and labelled insects from the same location which had been collected at the same time but were kept in large mass rearing cages. This was repeated for a maximum of three times.

Cages were examined daily for the duration of the experiment. At this time the number of newly laid eggs was noted. Eggs were painted with a water based dye (Rhodamine B) to facilitate recognition and left *in situ* until hatching. In addition, the locations where eggs were laid and the number of dead immatures and adults was also recorded. Recently eclosed adults were removed briefly from their respective cage and anaesthetised to allow measurement of their weight and to attach an identifying label. The experiments were mostly terminated when the eggs of the first generation adults hatched.

- Cages. The availability of cages determined the number of plant/insect combinations used each year. The cages used were constructed as follows:
- rows of 5 compartment wooden cages with double layer insect mesh partitions (the mesh between compartments was doubled to prevent insects from feeding on eucalypts in adjoining compartments). Each compartment had the following internal dimensions: 23.0 x 66.0 x 38.0 cm. Because of the cumbersome nature of these cages their original placements remained unchanged for the duration of the experiment. Combinations of eucalypts and bug species were assigned to cages at random. Each cage was given an identifying number and provisioned with a 20 ml bottle of alcohol to store and preserve dead insects for later examination if required. Cages were generally aligned in a north-south direction within the glasshouse to maximise the amount of light entering each.

- Glasshouse. No-choice experiments were conducted in the glasshouse described in Chapter 2. Complete temperature and humidity records for 1992 to 1995 are presented in Table 2.1.

- Specific trials.

1992/93. As the installation of cooling systems were incomplete at this time, glasshouse maximum temperature could rise unchecked in response to ambient changes, thus, manual cooling had to be initiated on extremely hot days. Insufficient field populations of *G. tasmanicus* could be located prior to commencing this experiment and thus the species was not able to be included. 17 cages using *A. obscuricornis* adults on different

Eucalyptus species were set up as follows:

- 4 cages of *E. morrisbyi* x *E. johnstonii*,
- 3 cages of *E. morrisbyi* x *E. ovata*,
- 2 cages each of *E. obliqua* and *Acmena smithii*,
- 1 cage each of *E. viminalis*; *E. pulchella*; *E. tenuiramis*; *E. ovata*; *E. amygdalina*; *E. delegatensis*.

Four *Acmena smithii* (Myrtaceae: subclass Rosidae) were included in this experiment to determine whether *A. obscuricornis* would survive and grow on non-eucalypts. This species was chosen because it belongs to the same family/subclass as *Eucalyptus* and because Schaefer and Mitchell (1983) reported that closely related Coreidae fed upon species of *Psidium* (Myrtaceae: Rosidae). In addition, 14 hybrid eucalypts (obtained from the Department of Plant Science, University of Tasmania) were also included to ascertain whether *A. obscuricornis* would develop on hybrids of endemic Tasmanian eucalypts. The majority of parent insects were collected from the University of Tasmania grounds on the 28 October 1992.

In a number of instances, procedures used in this first year's experiments were different to those used subsequently. Specifically, these include: **(a)** insects were not anaesthetised, weighed and given an identifying label; **(b)** eggs were not painted with Rhodamine B and the number of newly laid eggs was determined by the change in number from the preceeding day; **(c)** newly eclosed progeny were not weighed; **(d)** trees were not pruned during the course of the study; **(e)** the dividing mesh between conjoined cages was only one layer thick. A thermohygrograph was not available for monitoring glasshouse temperature and relative humidity. Temperature and humidity were recorded using a thermometer and hygrometer at the start of daily observations. These experiments were conducted from the 29 October 1992 to the 2 September 1993 (a few cages were cleaned prior to this date if all the insects within appeared dead).

1993/94. The following eucalypt/bug combinations were randomly divided among 20 wooden cages:

- 1 cage each of adult *A. obscuricornis* and *G. tasmanicus* on *E. nitens*; *E. globulus*; *E. gunnii*; *E. ovata*; *E. nitida*; *E. tenuiramis*; *E. pulchella*; *E. delegatensis*; *E. regnans*; *E. obliqua*.

Adult bugs were collected on the 24 September 1993 from a site near Brooks Bay, Tasmania. All the eucalypts used in this experiment were approximately 11 months old, except for the *E. regnans* which were 1½ to 2 years old, at the start of this experiment.

These experiments were conducted from the 27 September 1993 to the 7 April 1994.

1994/95. The following eucalypt/bug combinations were randomly divided among 30 wooden cages:

- 4 cages each of adult *A. obscuricornis* and *G. tasmanicus* on *E. regnans* and *E. delegatensis*,
- 2 cages of adult *A. obscuricornis* and 3 cages of adult *G. tasmanicus* on *E. coccifera*,
- 5 cages of adult *A. obscuricornis* on *E. tenuiramis*,
- 4 cages of adult *A. obscuricornis* on *E. globulus*.

The insects used in this experiment were collected from a site near Brooks Bay on the 14 October 1994. These eucalypts were approximately 12 months old at the start of the experiment. These experiments were conducted from the 15 October 1994 to the 10 April 1995. On the 2 March 1995 five to ten shoots were taken from caged control trees for water, nitrogen and carbon content analysis (see Chapter 2).

• Analyses. Given that the host plant performance of adults and nymphs has been assessed using different criteria, the results for these two developmental stages will be kept separate for each species. In similar studies of the host specificity of selected biological control agents, McFadyen (1983, 1987) and McFadyen and Marohasy (1990) simply list the number of plant species against which the agent was tested and then discuss performance in relation to important plant species. No specific details of relative suitability or any statistical analyses are presented. The results presented below will be presented in a similar fashion and only a limited number of analyses will be performed. In attempting to survey the host specificity of these insects across as wide a range of eucalypt species as possible, the range of possible statistical analyses which can be undertaken using the relatively poorly replicated data is limited. Thus, two-way analyses of variance of data collected for all eucalypt species tested and a subset of *Eucalyptus* species which had larger replicate numbers will be presented. Confidence intervals for adult survival, adult survival per mg, eggs, eggs per mg, percentage second instar mortality, percentage eclosion (*A. obscuricornis* only) and weight of eclosed offspring (*A. obscuricornis* only) for all eucalypts tested, and their respective subgenera, are also presented. Results are pooled across years and the assumption is made that the variation in longevity due to host plant effects is greater than the variation that may be due to insects being of different ages at the start of each year's trial

6.3. *Results*

6.3i. No-Choice Host Plant Performance Experiments

On the whole these experiments achieved the stated aims as *A. obscuricornis*, and to some extent *G. tasmanicus*, were able to be successfully reared under glasshouse conditions when given access to living eucalypts.

• Performance of *Amorbus obscuricornis* and *Gelonus tasmanicus* adults in relation to *Eucalyptus* species. A detailed summary of the performance of adult coreids of both species when confined to single *Eucalyptus* species is presented in Tables 6.1 and 6.2. Confidence intervals are presented in Figs 6.1-6.8 while the results of the two-way analyses of variance are presented in Table 6.3.

Adult *A. obscuricornis* fed and laid eggs on all the eucalypts tested. Adult insects also fed on the shoots of *Acmena smithii* causing characteristic apical wilting and laid a few eggs. Given that the adult insects used were field collected it is likely that egg production had commenced prior to capture, thus, it does not seem possible to suggest whether or not *A. smithii* was found to be a suitable oviposition host plant. This statement is also of some relevance to the findings concerning oviposition on the eucalypt species tested. Adult *A. obscuricornis* also found the two eucalypt hybrids tested to be very suitable host plants. Interestingly, these hybrids do not occur naturally.

Analysis of adult performance on all the eucalypts trialled, and those *Eucalyptus* species which were tested more than twice, revealed that eucalypt species had a very significant effect on all the performance criteria measured (Table 6.3 and Figs 6.1, 6.3). Longevity and egg production was most pronounced on species such as *E. nitens*, *E. gunnii*, *E. delegatensis*, *E. regnans* and *E. obliqua*. There was a positive correlation between female survival (d mg^{-1}) and number of eggs laid for both coreid species across all the eucalypt species tested. For example, for *A. obscuricornis*: $y = 6.64 + 118.00x$, $r^2 = 0.59$, and for *G. tasmanicus*: $y = 2.73 + 11.20x$, $r^2 = 0.46$.

When eucalypts were grouped according to subgenus, adult survival and eggs laid were not found to be significantly different between the two groups, however, longevity in d mg^{-1} and egg production in eggs mg^{-1} were significantly different between subgenera (Figs 6.2, 6.4). This may suggest that the initial weight of adults was a significant factor assisting survival and egg production on less suitable eucalypt species. Of the two subgenera, longevity (d mg^{-1}) and egg production (eggs mg^{-1}) was greater on species

belonging to *Eucalyptus* (Monocalyptus) than those of *Eucalyptus* (Symphyomyrtus). The significance of these finding was noticeably increased using the reduced data set pertaining to *E. delegatensis*, *E. globulus*, *E. regnans* and *E. tenuiramis* (for which greater numbers of replicates were available). Again, species such *E. delegatensis*, *E. regnans* and *E. tenuiramis* (Monocalyptus) were apparently more suitable for adults than *E. globulus* (Symphyomyrtus).

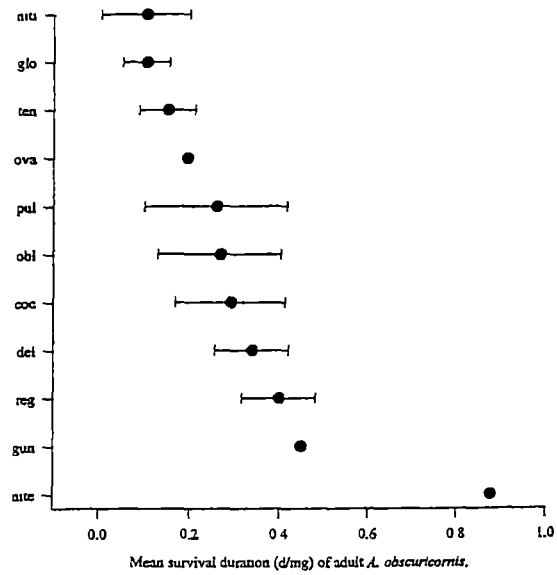
In general, adults of *G. tasmanicus* had shorter longevities and produced fewer eggs than *A. obscuricornis*, even on a per unit weight basis. Analysis of the data collected from all the eucalypts tested revealed that eucalypt species had a significant effect on the performance criteria recorded. Adult longevity and egg production was greatest on *E. regnans*, *E. nitens*, *E. obliqua* and *E. tenuiramis* (Table 6.2 and Figs 6.5, 6.7). Grouping these species according to subgenera revealed no significant differences in adult performance (Figs 6.6, 6.8). When a subset of this data was analysed (data for *E. coccifera*, *E. delegatensis* and *E. regnans*) there was found to be a significant difference in adult performance according to eucalypt group. *Eucalyptus* species belonging to the "ash" group (*E. regnans* and *E. delegatensis*) were found to be more suitable hosts than species belonging to the "gum" group (*E. coccifera*). Indeed, the only *G. tasmanicus* adults successfully reared in captivity came from *E. regnans* and *E. delegatensis*.

Table 6.1. No-choice performance of *Amorbus obscuricornis* adults on *Acmena smithii* and *Eucalyptus* species. Results presented as means ± se where appropriate. Ranges given in parathenses (N B. live weights of parent insects not determined in 1992/93. Subgenera, series and habitats for *Eucalyptus* species given in Table 4.2.)

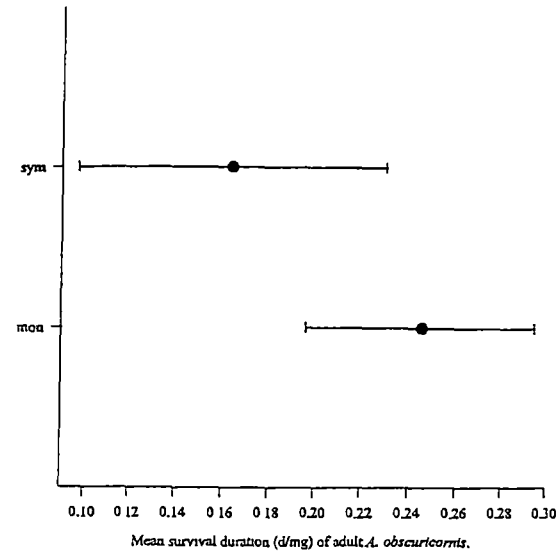
Host	Longevity ♂♂, d	Longevity ♂♂, d mg^{-1}	Longevity ♀♀, d	Longevity ♀♀, d mg^{-1}	Number of eggs	Eggs per mg ♀ live weight
Acmena smithii	11.0 [n = 2]	-	13 5 [n = 2]	-	8 0 [n = 2]	-
E. morrisbyi x *E. johnstonii*	110 5 ± 37 5 [n = 4] (59-222)	-	66 [n = 1]	-	60.5 ± 17.3 [n = 4] (27-97)	-
E. morrisbyi x *E ovata*	27.3 ± 8 5 [n = 3] (16-44)	-	39.7 ± 13 6 [n = 3] (13-58)	-	34.6 ± 15.9 [n = 3] (4-57)	-
E. amygdalina	16 [n = 1]	-	17 [n = 1]	-	7 [n = 1]	-
E coccifera	49.5 [n = 2]	0 406 [n = 2]	34.7 ± 11 8 [n = 3] (14-55)	0 214 ± 0 087 [n = 3] (0.078-0 376)	33 7 ± 15 2 [n = 3] (16-64)	0 213 ± 0.112 [n = 3] (0.089-0 437)
E delegatensis	43.6 ± 7.1 [n = 7] (6-68)	0 320 ± 0 058 [n = 6] (0 055-0.456)	50 8 ± 3.4 [n = 6] (43-64)	0.361 ± 0.055 [n = 5] (0 271-0.565)	83 2 ± 5.1 [n = 6] (63-96)	0 575 ± 0 077 [n = 5] (0 380-0.847)
E globulus	11.5 ± 2.3 [n = 17] (1-44)	0.097 ± 0 021 [n = 17] (0.007-0 4030)	18 1 ± 4 7 [n = 12] (5-53)	0 111 ± 0 028 [n = 12] (0 031-0 361)	14 5 ± 4 3 [n = 12] (0-52)	0 086 ± 0.022 [n = 12] (0-0.255)
E gunnii	55 [n = 1]	0.449 [n = 1]	-	-	103 [n = 1]	0 790 [n = 1]
E. nitens	125 [n = 1]	0 759 [n = 1]	192 [n = 1]	0 995 [n = 1]	108 [n = 1]	0.560 [n = 1]
E nitida	14 3 ± 3.0 [n = 4] (9-20)	0 108 ± 0 031 [n = 4] (0 054-0 198)	13 8 ± 5 5 [n = 4] (6-30)	0 095 ± 0 046 [n = 4] (0 035-0 231)	6 8 ± 1.7 [n = 4] (3-11)	0 041 ± 0 007 [n = 4] (0 035-0.056)
E. obliqua	56 8 ± 7 4 [n = 4] (44-77)	0 271 [n = 2]	55.3 ± 22 9 [n = 3] (10-83)	0 262 [n = 2]	36 8 ± 13.2 [n = 4] (8-72)	0 135 [n = 2]
E. ovata	17.5 [n = 2]	0 175 [n = 1]	23 5 [n = 2]	0 208 [n = 1]	12 0 [n = 2]	0 114 [n = 1]
E pulchella	24 3 ± 10 5 [n = 3] (11-45)	0 199 [n = 2]	33 0 [n = 2]	0.377 [n = 1]	21 0 [n = 2]	0 309 [n = 1]
E regnans	80.0 ± 33 2 [n = 4] (38-179)	0 545 ± 0 167 [n = 4] (0.305-1 041)	54.7 ± 17.4 [n = 7] (15-154)	0.316 ± 0.081 [n = 7] (0 081-0 744)	50 3 ± 9.5 [n = 7] (23-99)	0 315 ± 0 071 [n = 7] (0.124-0.647)
E tenuiramis	20.5 ± 4.5 [n = 13] (8-56)	0 150 ± 0 029 [n = 12] (0 042-0 346)	23 4 ± 3.5 [n = 9] (13-45)	0 148 ± 0 025 [n = 8] (0 078-0.283)	18 7 ± 5.3 [n = 9] (4-54)	0.116 ± 0 037 [n = 8] (0 022-0.340)
E vimnalis	13 [n = 1]	-	20 [n = 1]	-	5 [n = 1]	-

Table 6.2. No-choice performance of *Gelonus tasmanicus* adults on *Eucalyptus* species. Results presented as means ± se where appropriate. Ranges given in parathenses. (N.B. subgenera, series and habitats for *Eucalyptus* species given in Table 4.2.)

Host	Longevity ♂♂, d	Longevity ♂♂, d mg^{-1}	Longevity ♀♀, d	Longevity ♀♀, d mg^{-1}	Number of eggs	Eggs per mg ♀ live weight
E. coccifera	5.2 ± 0.7 [n = 17] (1-12)	0.128 ± 0.018 [n = 17] (0.023-0.340)	5.4 ± 0.8 [n = 15] (1-12)	0.070 ± 0.011 [n = 15] (0.013-0.156)	1.9 ± 0.5 [n = 15] (0-6)	0.023 ± 0.006 [n = 15] (0-0.078)
E. delegatensis	6.3 ± 0.8 [n = 29] (1-19)	0.166 ± 0 021 [n = 29] (0.022-0.467)	9.6 ± 1 6 [n = 17] (3-27)	0.126 ± 0 024 [n = 17] (0.036-0.408)	5.2 ± 1.1 [n = 18] (0-13)	0.061 ± 0.013 [n = 18] (0-0.159)
E. globulus	11.3 ± 1.6 [n = 6] (7-16)	0.285 ± 0 032 [n = 6] (0.182-0.398)	8.4 ± 1.8 [n = 5] (5-15)	0.114 ± 0.022 [n = 5] (0.067-0.186)	3.8 ± 1.5 [n = 5] (0-8)	0.047 ± 0.019 [n = 5] (0-0.099)
E. gunnii	10.8 ± 4.6 [n = 4] (3-24)	0.259 ± 0.106 [n = 4] (0.074-0.554)	14.8 ± 4.3 [n = 4] (7-26)	0.216 ± 0.085 [n = 4] (0.091-0.463)	4.0 ± 0.7 [n = 4] (3-6)	0.054 ± 0.008 [n = 4] (0.040-0.078)
E. nitens	38.7 ± 14.5 [n = 3] (19-67)	0.965 ± 0.366 [n = 3] (0.503-1.688)	33.5 [n = 2]	0.431 [n = 2]	12.5 [n = 2]	0.154 [n = 2]
E. nitida	8.0 ± 1.4 [n = 6] (3-13)	0.230 ± 0.049 [n = 6] (0 078-0.436)	10.2 ± 1.5 [n = 5] (5-14)	0.142 ± 0.031 [n = 5] (0.059-0.237)	4.2 ± 2.2 [n = 5] (0-11)	0.050 ± 0.026 [n = 5] (0-0 011)
E. obliqua	28.0 ± 6.7 [n = 3] (19-41)	0.704 ± 0.150 [n = 3] (0.522-1.002)	91.5 [n = 2]	1.345 [n = 2]	7.5 [n = 1]	0.099 [n = 2]
E. ovata	11.8 ± 3.8 [n = 6] (3-23)	0.306 ± 0.092 [n = 6] (0.093-0.610)	14.3 ± 6.6 [n = 4] (6-34)	0.234 ± 0.150 [n = 4] (0.077-0.683)	7.5 ± 1.9 [n = 4] (3-12)	0.090 ± 0.014 [n = 4] (0.060-0.115)
E. pulchella	9.0 ± 1.5 [n = 4] (5-12)	0.223 ± 0 030 [n = 4] (0.149-0.294)	7 3 ± 2.0 [n = 4] (4-13)	0.106 ± 0.029 [n = 4] (0.051-0.184)	3.6 ± 1.6 [n = 5] (0-7)	0.041 ± 0.017 [n = 5] (0-0.079)
E. regnans	23.0 ± 11.9 [n = 6] (7-82)	0.639 ± 0.343 [n = 6] (0.210-2.350)	80.2 ± 20.9 [n = 5] (25-130)	1.141 ± 0 335 [n = 5] (0.281-2.281)	18.3 ± 5.7 [n = 6] (8-46)	0.278 ± 0.108 [n = 6] (0.083-0.807)
E. tenuiramis	39.5 [n = 2]	1.119 [n = 2]	20 7 ± 5.5 [n = 3] (12-31)	0.285 ± 0.072 [n = 3] (0.198-0.428)	9.0 ± 0.6 [n = 3] (8-10)	0.125 ± 0.004 [n = 3] (0.120-0.132)



6.1



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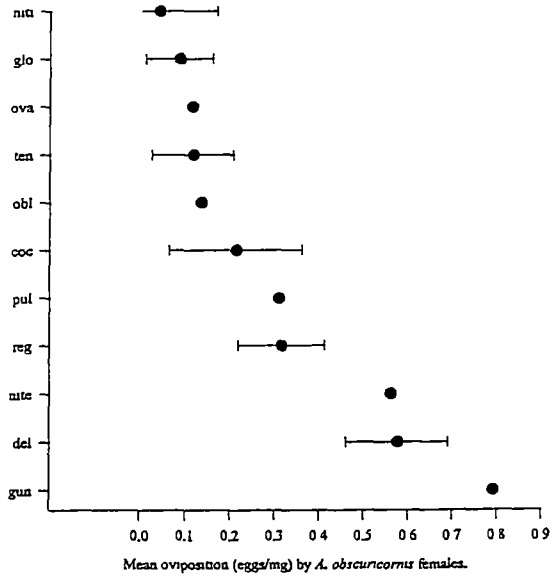

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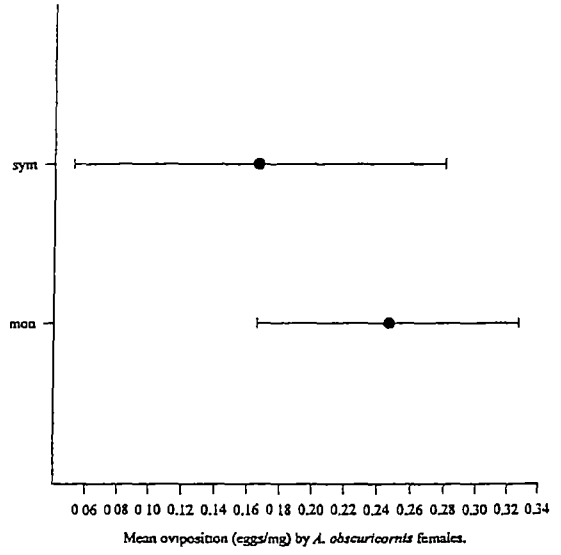
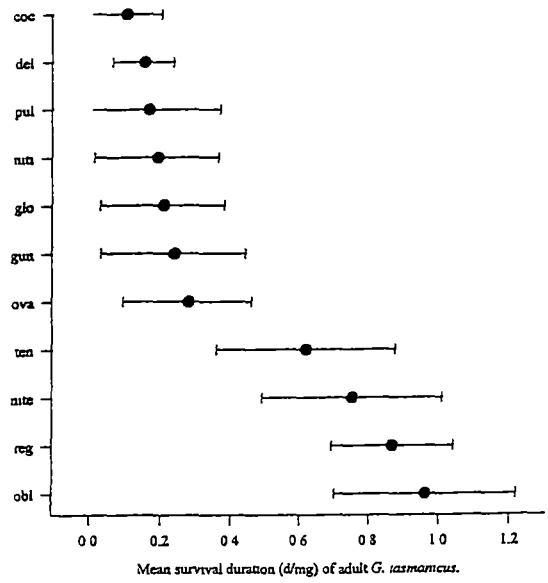


6.4

Figs 6.1-6.4. Individual 95% confidence intervals based on pooled standard deviation for mean: **(6.1)** survival duration (d/mg) of *A. obscuricornis* adults according to *Eucalyptus* species; **(6.2)** survival duration (d/mg) of *A. obscuricornis* adults according to eucalypt subgenus; **(6.3)** oviposition (eggs/mg) by *A. obscuricornis* females according to *Eucalyptus* species; **(6.4)** oviposition (eggs/mg) by *A. obscuricornis* females according to eucalypt subgenus. (Key: coc = *E. coccifera*; niti = *E. nitida*; gun = *E. gunnii*; reg = *E. regnans*; nite = *E. nitens*; ova = *E. ovata*; glo = *E. globulus*; ten = *E. tenuiramis*; del = *E. delegatensis*; pul = *E. pulchella*; obl = *E. obliqua*; mon = *Eucalyptus* (Monocalyptus); sym = *Eucalyptus* (Symphyomyrtus). N.B. Confidence intervals for means based on less than three observations not presented.)



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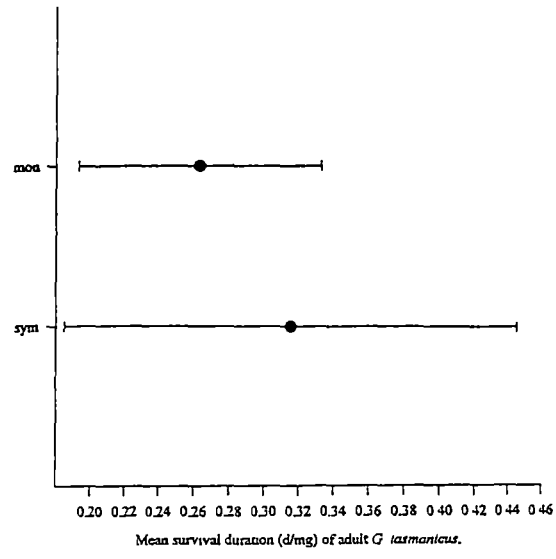

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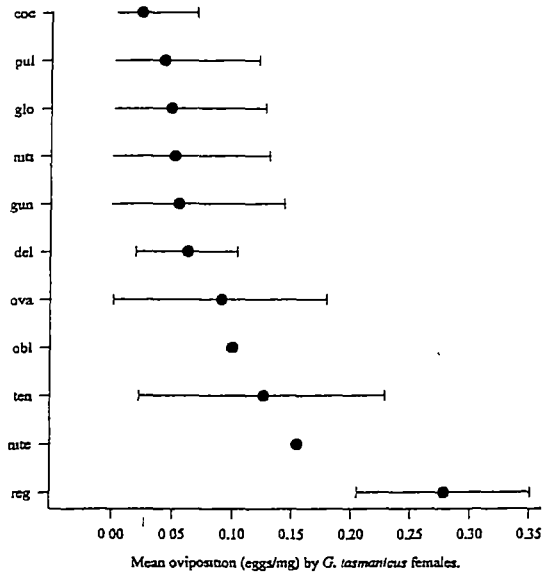

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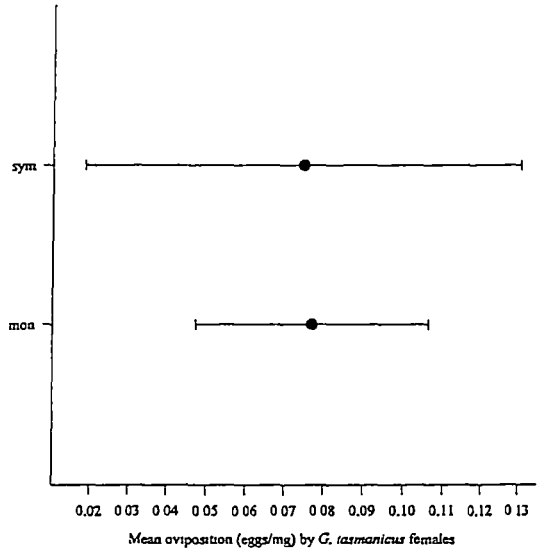


6.8

Figs 6.5-6.8. Individual 95% confidence intervals based on pooled standard deviation for mean: **(6.5)** survival duration (d/mg) of *G. tasmanicus* adults according to *Eucalyptus* species; **(6.6)** survival duration (d/mg) of *G. tasmanicus* adults according to eucalypt subgenus; **(6.7)** oviposition (eggs/mg) by *G. tasmanicus* females according to *Eucalyptus* species; **(6.8)** oviposition (eggs/mg) by *G. tasmanicus* females according to eucalypt subgenus. (Key: coc = *E. coccifera*; niti = *E. nitida*; gun = *E. gunnii*; reg = *E. regnans*; nite = *E. nitens*; ova = *E. ovata*; glo = *E. globulus*; ten = *E. tenuiramis*; del = *E. delegatensis*; pul = *E. pulchella*; obl = *E. obliqua*; mon = *Eucalyptus* (Monocalyptus); sym = *Eucalyptus* (Symphyomyrtus). N.B. Confidence intervals for means based on less than three observations not presented.)

Table 6.3. Results of two-way analyses of variance using *Amorbus obscuricornis* and *Gelonus tasmanicus* adult performance data from Table 6.1 and 6.2. (N.B. See materials and methods for explanation behind choice of analysis.)

Species, Factor/data	Adult survival (d)	Adult survival (d mg^{-1})	Eggs laid	Eggs laid per mg ♀ weight
A. obscuricornis				
Eucalyptus spp. (full data set less *A. smithii*)	$F_{14, 106} = 10.00$, $p < 0.001$	$F_{10, 84} = 11.98$, $p < 0.001$	$F_{14, 44} = 7.28$, $p < 0.001$	$F_{10, 33} = 10.61$, $p < 0.001$
Eucalyptus subgenus	$F_{1, 106} = 0.64$, $p = 0.424$	$F_{1, 84} = 8.46$, $p = 0.005$	$F_{1, 44} = 1.11$, $p = 0.297$	$F_{1, 33} = 4.26$, $p = 0.047$
Eucalyptus spp. (*E. delegatensis*, *E. globulus*, *E. regnans*, *E. tenuiramis* only)	$F_{3, 70} = 20.89$, $p < 0.001$	$F_{3, 66} = 25.34$, $p < 0.001$	$F_{3, 29} = 189.98$, $p < 0.001$	$F_{3, 27} = 72.36$, $p < 0.001$
Eucalyptus subgenus	$F_{1, 70} = 27.14$, $p < 0.001$	$F_{1, 66} = 34.98$, $p < 0\ 001$	$F_{1, 29} = 194.79$, $p < 0.001$	$F_{1, 27} = 75.34$, $p < 0.001$
G. tasmanicus				
Eucalyptus spp. (full data set)	$F_{10, 140} = 10.75$, $p < 0.001$	$F_{10, 140} = 11.75$, $p < 0.001$	$F_{10, 57} = 4.42$, $p < 0.001$	$F_{10, 57} = 4.05$, $p < 0.001$
Eucalyptus subgenus	$F_{1, 140} = 0.24$, $p = 0.626$	$F_{1, 140} = 0.85$, $p = 0.357$	$F_{1, 57} = 0.02$, $p = 0.893$	$F_{1, 57} = 0.01$, $p = 0.936$
Eucalyptus spp. (*E. coccifera*, *E. delegatensis*, *E. regnans* only)	$F_{2, 85} = 34.60$, $p < 0.001$	$F_{2, 85} = 34.91$, $p < 0\ 001$	$F_{2, 35} = 20.79$, $p < 0.001$	$F_{2, 35} = 15.35$, $p < 0.001$
Eucalyptus group*	$F_{1, 85} = 8.61$, $p = 0.004$	$F_{1, 85} = 9.65$, $p = 0.003$	$F_{1, 35} = 14.12$, $p = 0.001$	$F_{1, 35} = 8.42$ $p = 0.006$

* not possible to conduct analysis using subgenus as all species belong to the *Monocalyptus*; groups are: *E. coccifera*, gum and *E. delegatensis* and *E. regnans*, ash.

• Performance of *Amorbus obscuricornis* and *Gelonus tasmanicus* nymphs in relation to *Eucalyptus* species. The performance of nymphs of both species on various eucalypts is summarised in Tables 6.4 and 6.5, whilst, confidence intervals are presented in Figs 6.9-6.16 and the results of analyses are detailed in Table 6.6.

Immatures of *Amorbus obscuricornis* were successfully reared through to adults on most of the plant species tested, the exceptions being *Acmena smithii*, *E. amygdalina* and *E. viminalis*. On *A. smithii* no nymphs passed the second instar. Mortality of second instar *A. obscuricornis* was generally very high, often around 50%, irrespective of the host eucalypt (Table 6.4 and Fig. 6.9). Apparently the successful commencement of feeding in this instar (see section 5.3iii) is a crucial period in nymphal developmental. Nymphs which successfully ecdysed to the third instar were likely to eclose irrespective of the eucalypt host (see Fig. 6.11).

Eucalypts which were found to be good adult hosts for *A. obscuricornis* were generally also favourable species for nymphal development. For example, the heaviest adults were reared on species such as *E. globulus*, *E. tenuiramis*, *E. gunnii*, *E. coccifera*, *E. delegatensis* and *E. obliqua* (Table 6.4 and Fig. 6.13). Analysis of all the available data revealed that *Eucalyptus* species had a significant effect on the mortality rate of second instars and the weight of eclosed offspring, but not on percentage eclosion. These findings were still apparent using the reduced data set (Table 6.6). This suggests that once nymphs of this species pass the second instar host eucalypt is unlikely influence survival to the adult. This relationship was still apparent if the eucalypts were grouped according to subgenus.

Interestingly, although the mortality rate of second instars was higher on species belonging to *Eucalyptus* (Symphyomyrtus) than on *Eucalyptus* (Monocalyptus) (Fig. 6.10) the weight of eclosed adults was greater on species belonging to *Eucalyptus* (Symphyomyrtus) (Fig. 6.14). For example, the heaviest adults were reared on *E. globulus* (Symphyomyrtus). This indicates that should third instar *A. obscuricornis* nymphs become established on *Eucalyptus* (Symphyomyrtus) species they are likely to attain heavier live weights upon eclosion than on *Eucalyptus* (Monocalyptus) species.

Nymphs of *G. tasmanicus* were found to be very difficult to rear irrespective of the host plant. In this species, mortality at the second instar was considerably higher, on average, than for *A. obscuricornis* (Table 6.5 and Fig. 6.15). Of the eucalypt species tested only

eight adults eclosed; one on *E. delegatensis* and seven on *E. regnans*. Analysis of the data revealed that *Eucalyptus* species had a significant effect on percentage second instar mortality (Table 6.6). When the eucalypts were grouped according to subgenus and the analysis performed there was found to be no difference between *Eucalyptus* (Monocalyptus) or *Eucalyptus* (Symphyomyrtus) (Fig. 6.16 and Table 6.6). Analysis using a reduced data subset revealed that eucalypt group had a significant effect on percentage mortality of second instar nymphs. Mortality was found to be higher on gums (namely *E. coccifera*) than on ashes (namely *E. delegatensis* and *E. regnans*) (Table 6.6). These findings should be viewed as preliminary given the low level of replication.

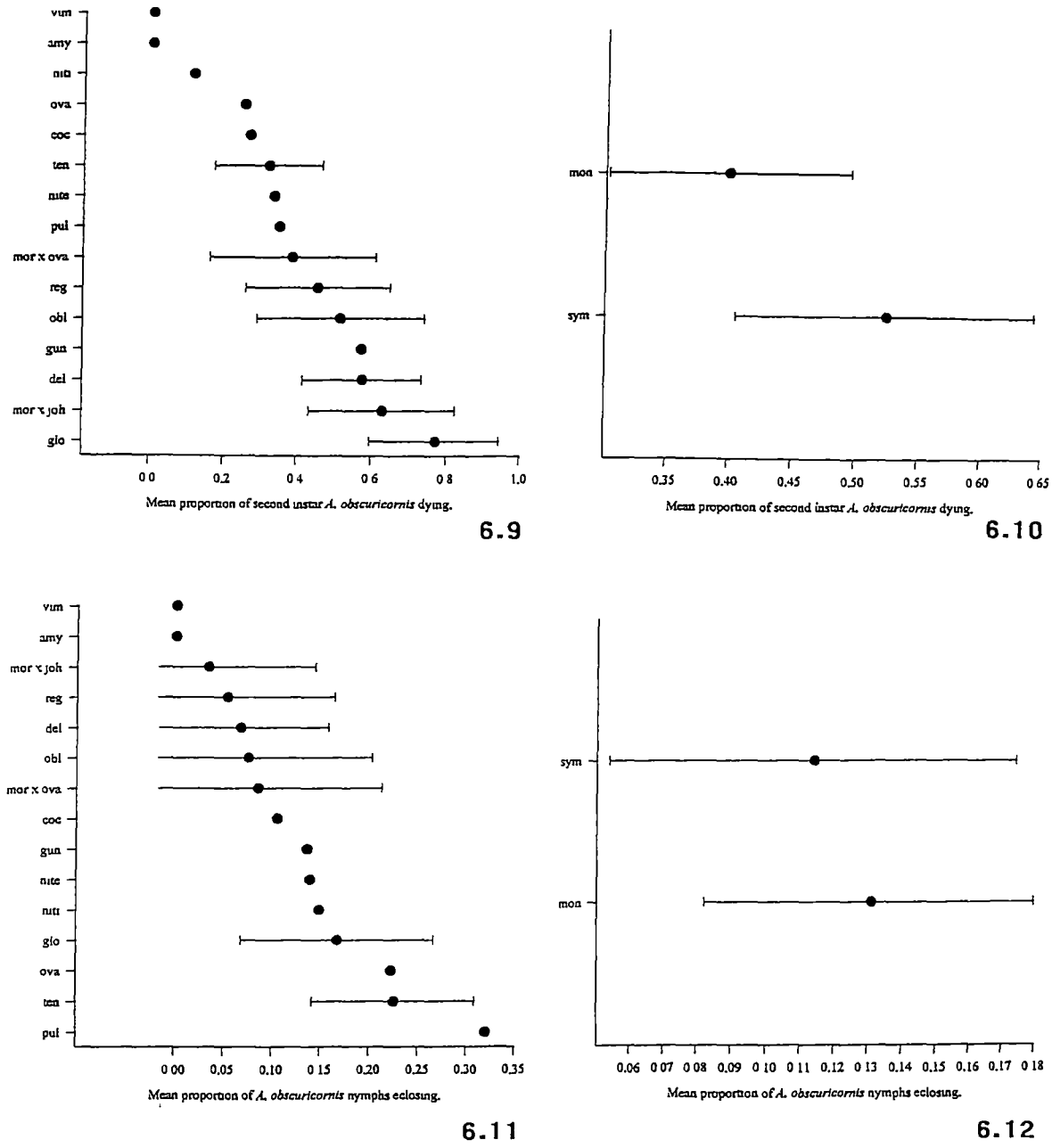
Table 6.4. No-choice performance of *Amorbus obscuricornis* nymphs on *Acmena smithii* and *Eucalyptus* species. Results presented as means ± se where appropriate. Percentage eclosion based on number of eggs (predominantly) or number of dead nymphs (denoted by *) which ever was larger. Ranges given in parathenses. (N.B. live weights newly eclosed adults not determined in 1992/93. Subgenera, series and habitats for *Eucalyptus* species given in Table 4.2.)

Host	Total number eggs	Total dead nymphs	% second instar mortality	% eclosion	Weight ♂♂ (mg)	Weight ♀♀ (mg)
Acmena smithii	16	14	100 [n = 2]	0 [n = 1]	-	-
E. morrisbyi x *E. johnstonii*	242	204	62 8 [n = 4] (55.7-69 6)	3 3 [n = 4] (0-11 1)	-	-
E. morrisbyi x *E. ovata*	104*	105	38.5 [n = 3] (16.7-51 0)	8.5 [n = 3] (0-16 7)	-	-
E amygdalina	7	7	0 [n = 1]	0 [n = 1]	-	-
E. coccifera	101	78	26 6 [n = 2]	10 5 [n = 2]	101 2 ± 9.7 [n = 4] (84 5-127.0)	118 9 ± 9.8 [n = 8] (82 5-158 4)
E. delegatensis	499	396	57 5 [n = 6] (49.1-91 7)	6 7 [n = 6] (0-16.7)	100 5 ± 8.6 [n = 13] (62 2-151.8)	112.3 ± 6.3 [n = 13] (76 1-151 8)
E globulus	174	104	77.0 [n = 5] (61.5-100)	16 7 [n = 5] (0-39.3)	146.6 ± 10.9 [n = 14] (94.9-224 2)	130.1 ± 7.5 [n = 17] (89.4-198 8)
E. gunnii	103	35	57 1 [n = 1]	13 6 [n = 1]	137.2 ± 10 3 [n = 6] (100 3-177.9)	118 0 ± 10.6 [n = 8] (89 0-176 4)
E nitens	108	75	33 3 [n = 1]	13 9 [n = 1]	99 6 ± 4 8 [n = 6] (88.4-115 3)	99.6 ± 7.5 [n = 9] (69.2-135 4)
E. nitida	27	9	11 1 [n = 1]	14 8 [n = 1]	87 2 ± 5 8 [n = 4] (75.1-102 8)	-
E. obliqua	147	119	51 4 [n = 3] (16.7-82.6)	7.5 [n = 3] (4.7-9 4)	107 9 [n = 2]	-
E. ovata	24	9	25 0 [n = 2]	22 3 [n = 2]	98 5 [n = 2]	93 1 ± 10.5 [n = 3] (72.9-107 8)
E. pulchella	42*	43	34 8 [n = 2]	32 0 [n = 2]	96 6 ± 7.9 [n = 6] (70.9-126 0)	108 1 [n = 2]
E regnans	352	201	45.4 [n = 4] (17 1-60.4)	5 3 [n = 4] (3.0-8 5)	71 5 ± 8 8 [n = 4] (60 1-97.1)	85.3 ± 5 1 [n = 13] (62 7-121.4)
E. tenuiramis	168	123	31.8 [n = 7] (11 1-44.5)	22 5 [n = 7] (4 3-46 2)	143.4 ± 10 0 [n = 13] (73 5-197.1)	130.3 ± 6.3 [n = 15] (77 8-170.7)
E. vimmalis	5	2	0 [n = 1]	0 [n = 1]	-	-

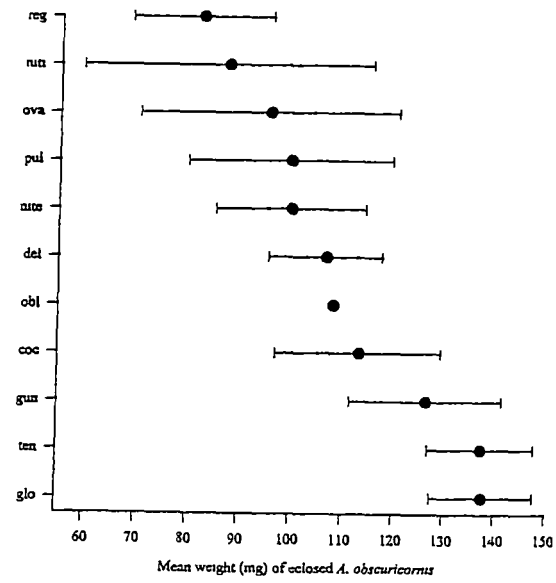
* some eggs not located following oviposition.

Table 6.5. No-choice performance of *Gelonus tasmanicus* nymphs on *Eucalyptus* species Results presented as means ± se where appropriate. Percentage eclosion based on number of eggs. Ranges given in parathenses. (N.B. subgenera, series and habitats for *Eucalyptus* species given in Table 4.2.)

Host	Total number eggs	Total dead nymphs	% second instar mortality	% eclosion	Weight ♂♂ (mg)	Weight ♀♀ (mg)
E. coccifera	28	24	78.6 [n = 3] (66.7-100)	0 [n = 3]	-	-
E. delegatensis	93	70	78.0 [n = 5] (58.8-100)	0.6 [n = 5]	40 3 [n = 1]	-
E. globulus	19	14	85.7 [n = 1]	0 [n = 1]	-	-
E. gunnii	16	4	50.0 [n = 1]	0 [n = 1]	-	-
E. nitens	25	17	82.4 [n = 1]	0 [n = 1]	-	-
E. nitida	21	7	100 [n = 1]	0 [n = 1]	-	-
E. obliqua	15	3	0 [n = 1]	0 [n = 1]	-	-
E. ovata	30	14	92.9 [n = 1]	0 [n = 1]	-	-
E. pulchella	18	4	100 [n = 1]	0 [n = 1]	-	-
E. regnans	110	58	33.5 [n = 5]	8.3 [n = 5] (0-30 8)	32.6 [n = 2]	44.7 ± 1.6 [n = 5] (39.8-47.7)
E. tenuiramis	27	10	90.0 [n = 1]	0 [n = 1]	-	-



Figs 6.9-6.12. Individual 95% confidence intervals based on pooled standard deviation for mean: **(6.9)** proportion of second instar *A. obscuricornis* nymphs dying according to *Eucalyptus* species; **(6.10)** proportion of second instar *A. obscuricornis* nymphs dying according to eucalypt subgenus; **(6.11)** proportion of *A. obscuricornis* nymphs eclosing according to *Eucalyptus* species; **(6.12)** proportion of *A. obscuricornis* nymphs eclosing according to eucalypt subgenus. (Key: vim = *E. viminalis*; amy = *E. amygdalina*; mor x joh = *E. morrisbyi* x *E. johnstonii*; mor x ova = *E. morrisbyi* x *E. ovata*; coc = *E. coccifera*; niti = *E. nitida*; gun = *E. gunnii*; reg = *E. regnans*; nite = *E. nitens*; ova = *E. ovata*; glo = *E. globulus*; ten = *E. tenuiramis*; del = *E. delegatensis*; pul = *E. pulchella*; obl = *E. obliqua*; mon = *Eucalyptus* (Monocalyptus); sym = *Eucalyptus* (Symphyomyrtus). N.B. Confidence intervals for means based on less than three observations not presented.)



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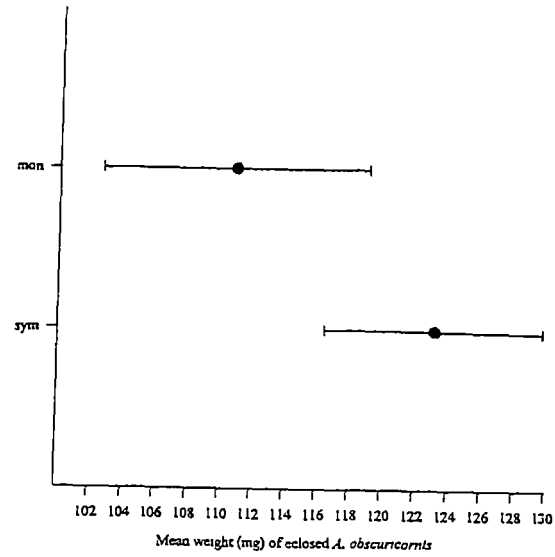

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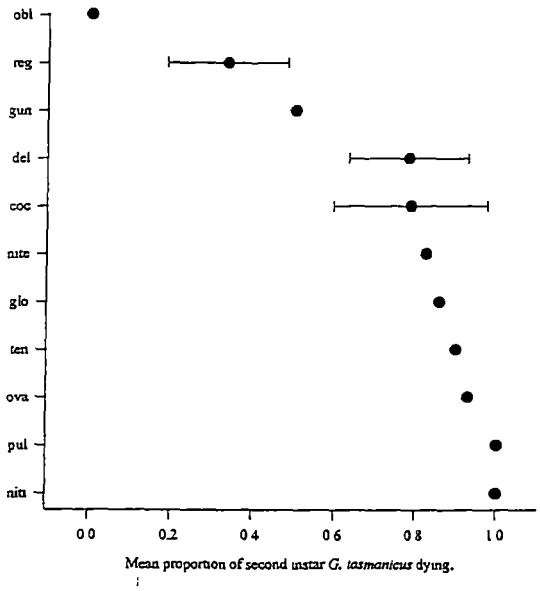

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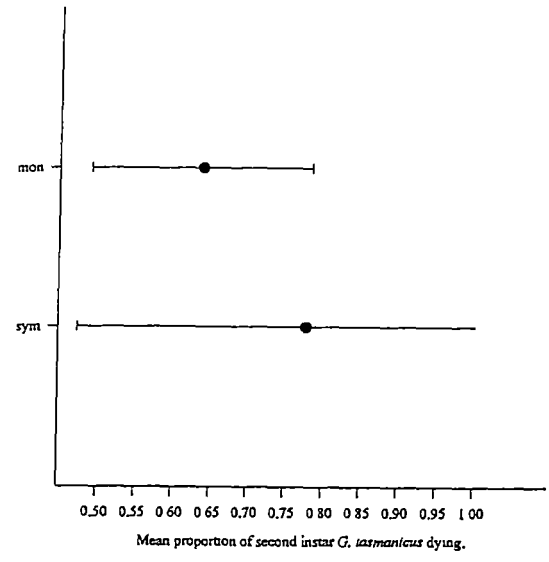


6.16

Figs 6.13-6.16. Individual 95% confidence intervals based on pooled standard deviation for mean: **(6.13)** weight (mg) of eclosed *A. obscuricornis* according to *Eucalyptus* species; **(6.14)** weight (mg) of eclosed *A. obscuricornis* according to eucalypt subgenus; **(6.15)** proportion of second instar *G. tasmanicus* nymphs dying according to *Eucalyptus* species; **(6.16)** proportion of second instar *G. tasmanicus* nymphs dying according to eucalypt subgenus. (Key: coc = *E. coccifera*; niti = *E. nitida*; gun = *E. gunnii*; reg = *E. regnans*; nite = *E. nitens*; ova = *E. ovata*; glo = *E. globulus*; ten = *E. tenuiramis*; del = *E. delegatensis*; pul = *E. pulchella*; obl = *E. obliqua*; mon = *Eucalyptus* (Monocalyptus); sym = *Eucalyptus* (Symphyomyrtus). N.B. Confidence intervals for means based on less than three observations not presented.)

Table 6.6. Results of two-way analyses of variance using *Amorbus obscuricornis* and *Gelonus tasmanicus* nymphal performance data from Table 6.4 and 6.5. (N.B. See materials and methods for explanation behind choice of analysis.)

Species, Factor/data	% second instar mortality	% eclosion	Weight of eclosed offspring
A. obscuricornis			
Eucalyptus spp. (full data set less *A. smithii*)	$F_{14, 27} = 3.44$, $p = 0.003$	$F_{14, 27} = 1.67$, $p = 0.123$	$F_{10, 151} = 8.41$, $p < 0.001$
Eucalyptus subgenus	$F_{1, 27} = 4.90$, $p = 0.035$	$F_{1, 27} = 0.23$, $p = 0.634$	$F_{1, 151} = 7.490$ $p = 0.006$
Eucalyptus spp. (*E. delegatensis*, *E. globulus*, *E. regnans*, *E. tenuiramis* only)	$F_{3, 18} = 9.09$, $p = 0.001$	$F_{3, 18} = 2.53$, $p = 0.090$	$F_{14, 98} = 20.26$, $p < 0.001$
Eucalyptus subgenus	-#	-#	$F_{1, 98} = 16.58$, $p < 0\ 001$
G. tasmanicus			
Eucalyptus spp. (full data set)	$F_{10, 9} = 6\ 71$, $p = 0.004$	-‡	-†
Eucalyptus subgenus	$F_{1, 9} = 2.79$, $p = 0.129$	-‡	-†
Eucalyptus spp. (*E. coccifera*, *E. delegatensis*, *E. regnans* only)	$F_{2, 9} = 18.63$, $p = 0.001$	-‡	-†
Eucalyptus group*	$F_{1, 9} = 7.33$, $p = 0.024$	-‡	-†

not possible to conduct two-way analysis using subgenera due to negative sums squares.

‡ nymphs eclosed only on *E. regnans* and *E. delegatensis*.

† too few insects eclosed for analysis.

* not possible to conduct analysis using subgenus as all species belong to the *Monocalyptus*; groups are: *E. coccifera*, gum and *E. delegatensis* and *E. regnans*, ash.

• Adult and nymphal performance of *Amorbus obscuricornis* and *Gelonus tasmanicus* in relation to shoot water content and C/N ratio. The water, nitrogen and carbon contents and C/N ratio of eucalypt shoots sampled are presented in Table 6.7. The ratio of C to N is used throughout these results because it relates two elements that form the basis of compounds which significantly affect the nutrition of sucking insects in particular, namely amino acids/secondary compounds and photosynthetic sugars (Kennedy and Booth 1951; Kennedy 1958; van Emden and Bashford 1971; van Emden 1972, 1978; Kidd 1985; Bernays 1985; Slansky and Scriber 1985; Kidd *et al.* 1990; Carver *et al.* 1991). Moreover, the proportion of C to N is often used throughout the biological sciences (e.g. Shaw and Little 1972; Bryant *et al.* 1983). As illustrated in Table 6.7, a high C/N ratio corresponds to a low shoot nitrogen concentration and vice versa. Shoot water content was found to be negatively correlated to shoot C/N ratio (regression equation: $y = 159.00 - 1.95x$, where the $r^2 = 0.93$). Thus, in nutritional terms shoots with high water contents should be preferable due to their comparatively low carbon/high nitrogen concentrations.

Table 6.7. Water, nitrogen and carbon contents, and the C/N ratio, of eucalypt shoots from control trees grown under glasshouse conditions during 1994/95. Results are averages and elements are given as total percentage composition.

Eucalyptus spp.	% water	% nitrogen	% carbon	C/N ratio
E. coccifera, n = 2 trees	74.4	3.31	48.00	14.5 : 1
E. delegatensis, n = 4 trees	72.6	2.63	48.55	18.5 : 1
E. regnans, n = 4 trees	70.6	2.45	50.91	20.8 : 1
E. tenuiramis, n = 2 trees	74.6	3.85	47.98	12.5 : 1

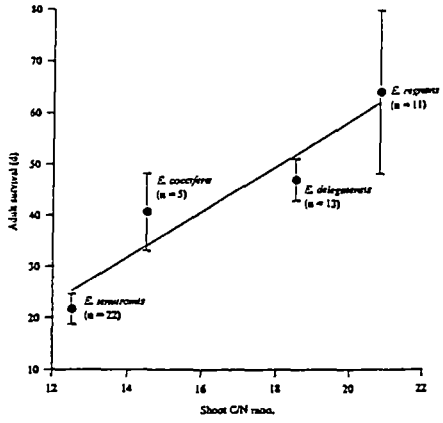
The relationships between shoot C/N ratio, water content and the performance of *A. obscuricornis* and *G. tasmanicus* are illustrated in Figs 6.17-6.22 and 6.23-6.26, respectively. The relationship between the weight of *G. tasmanicus* offspring and eucalypt shoot C/N ratio and shoot water content was not considered given the meagre number of adults which eclosed (see Table 6.5). The performance data utilised are cumulative results from experiments conducted from 1992 to 1995 and are summed according to eucalypt species. Adult survival was averaged for males and females. Similarly, the weight of eclosed *A. obscuricornis* offspring is averaged for male and female insects. Nitrogen, carbon and water content analyses were conducted using shoots from 1994/95 control trees, thus, although these trees were from the same seedlot as those used during this experiment and were grown under identical conditions these trees were not exposed to feeding coreids. Therefore, it is possible that feeding insects were

reared on eucalypts with different water and C/N ratios to those analysed. For this reason these results should not be considered definitive; rather they should be viewed as explorative of actual relationships.

For adult *A. obscuricornis* there was a positive linear relationship between longevity and C/N ratio, while for water content the relationship was negative (Figs 6.17, 6.18). Thus, longevity of *A. obscuricornis* adults was most pronounced on eucalypt species with high carbon and low shoot water contents.

Female *A. obscuricornis* produced the most eggs on *E. delegatensis* which had a shoot C/N ratio and water content intermediate between *E. regnans* and *E. coccifera* (Figs 6.19, 6.20); while *E. tenuiramis* produced the heaviest adult offspring with those reared on *E. regnans* being the lightest. A negative linear correlation between weight of offspring and C/N ratio was observed, while there was a positive linear relationship between shoot water content and weight of offspring (Figs 6.21 and 6.22).

The results concerning the performance of adult *G. tasmanicus* on the four species under consideration are not easily explained. Adult longevity and egg production were greatest on those species which either had the highest or the lowest shoot C/N ratio and water contents (Figs 6.23-6.26). Performance was lowest on those species with intermediate shoot C/N ratios and water contents. Further detailed investigations would be required to elucidate the significance of these preliminary findings. These results would suggest that the nutritional requirements and/or response to secondary plant metabolites in this species differ markedly from those of *A. obscuricornis*.



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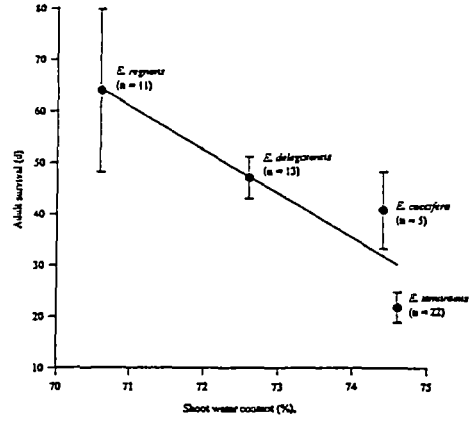

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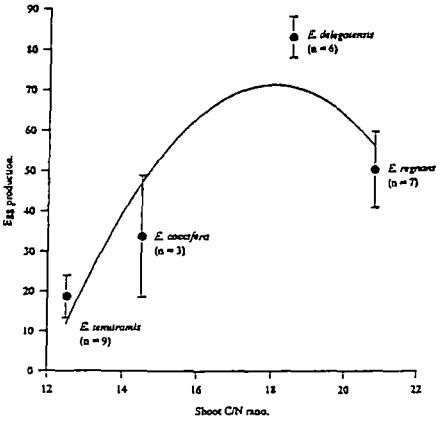

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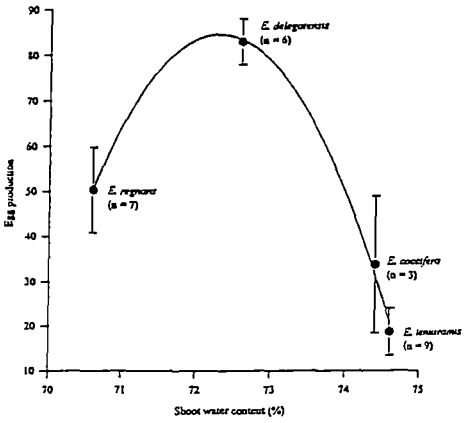

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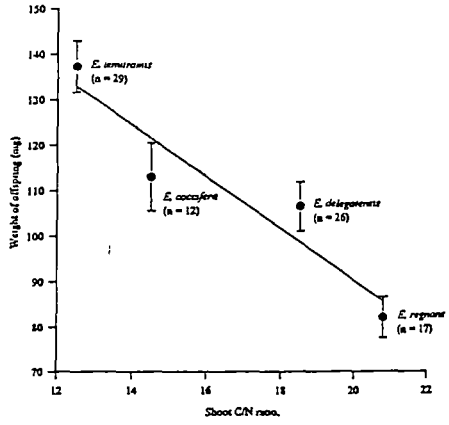

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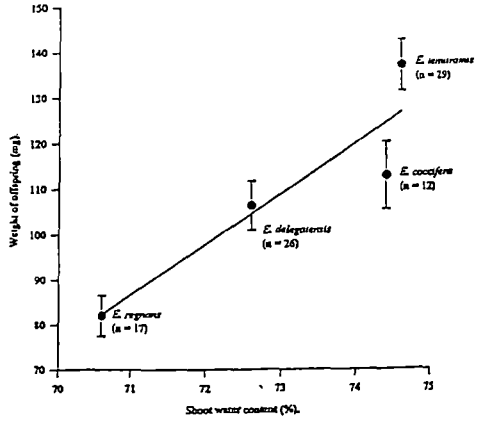
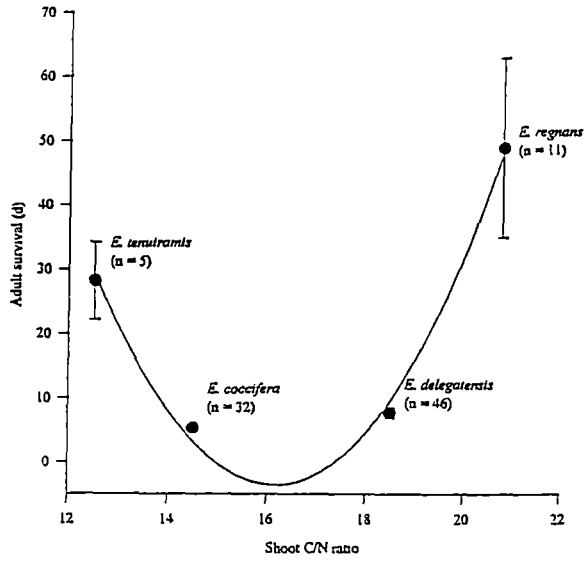


6.22

Figs 6.17-6.22. Performance of *A. obscuricornis* using: (**6.17**) adult survival versus C/N ratio ($y = - 29.91 + 4.42x$, $r^2 = 0.91$); (**6.18**) adult survival versus water content ($y = 668.05 - 8.55x$, $r^2 = 0.84$); (**6.19**) egg production versus C/N ratio ($y = - 565.06 + 70.69x - 1.96x^2$, $r^2 = 0.82$); (**6.20**) egg production versus water content ($y = - 62871.86 + 1741.69x - 12.05x^2$, $r^2 = 1.00$); (**6.21**) weight of offspring versus C/N ratio ($y = 204.31 - 5.71x$, $r^2 = 0.89$); (**6.22**) weight of offspring versus water content ($y = - 705.96 + 11.17x$, $r^2 = 0.84$).



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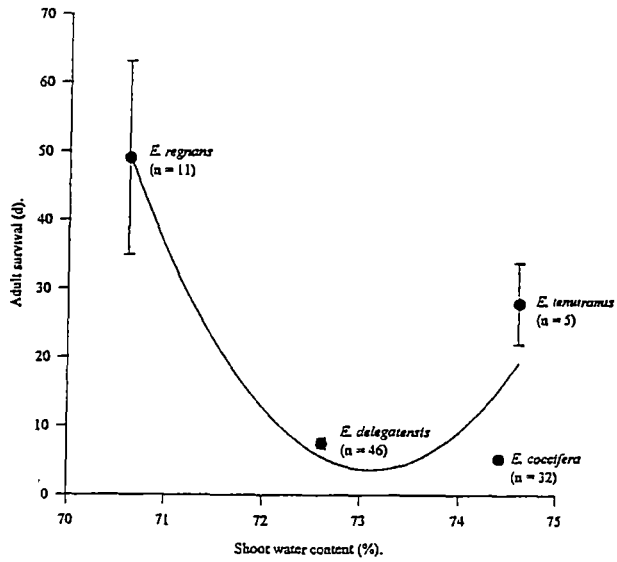

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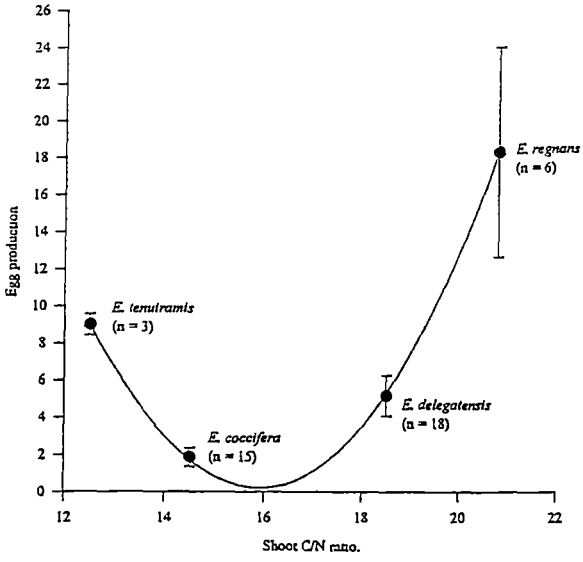

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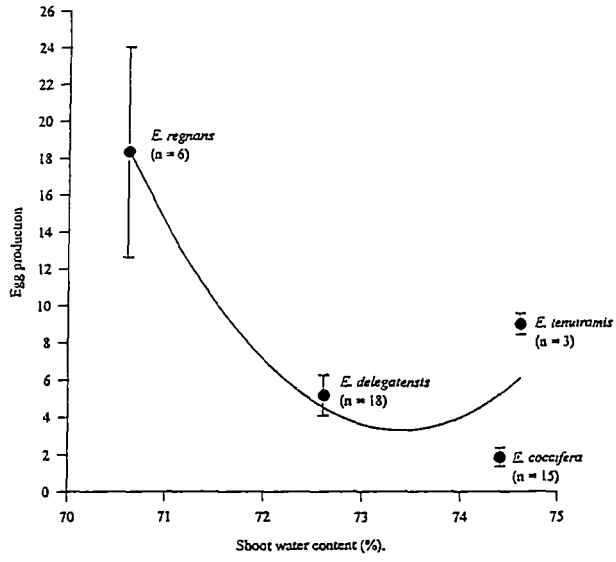

6.26

Figs 6.23-6.26. Performance of *G. tasmanicus* using: (**6.23**) adult survival versus C/N ratio ($y = 631.28 - 78.48x + 2.43x^2$, $r^2 = 0.99$); (**6.24**) adult survival versus water content ($y = 38545.13 - 1054.20x + 7.21x^2$, $r^2 = 0.85$); (**6.25**) egg production versus C/N ratio ($y = 192.02 - 24.10x + 0.76x^2$, $r^2 = 1.00$); (**6.26**) egg production versus water content ($y = 10470.51 - 285.23x + 1.94x^2$, $r^2 = 0.87$).

6.4. *Discussion*

6.4i. Host Specificity and Degree of Polyphagy of *Amorbus obscuricornis* and *Gelonus tasmanicus*.

The studies detailed here illustrate the diversity of *Eucalyptus* species on which adults and nymphs of *A. obscuricornis* are able to reproduce and grow. These findings, together with the host plant records detailed in Chapters 4 (specifically Table 4.3) and 7 (Table 7.2), indicate that this species is oligophagous for species of *Eucalyptus*, with performance being influenced by specific insect-plant interactions. For example, host plant architecture influences the suitability of eucalypts to facilitate nymphal development (as mentioned below and developed more fully in the next chapter). In *A. obscuricornis*, adult performance and nymphal survival was optimal on *Eucalyptus* (Monocalyptus), however, nymphs which became established on *Eucalyptus* (Symphyomyrtus) species were likely to mature into heavier adults. It was observed that the hosts which were most suitable for adults also favoured optimal survival and growth of immatures. Females on unsuitable host plants, e.g. *Acmena smithii*, laid only a few eggs before dying. Although the females used in these experiments had no choice concerning oviposition host plant, their performance was found to reflect that of their offspring. These results lend some support for optimal host plant selection by ovipositing females as per Jaenike (1978), in that females laid more eggs on those hosts which enhanced nymphal survival.

The host performance studies of *G. tasmanicus* could be interpreted as indicating that this insect is less polyphagous than *A. obscuricornis*, especially when nymphal development is considered, i.e. only *E. regnans* and *E. delegatensis* were apparently able to sustain nymphal growth until eclosion. However, the collection records detailed in Table 4.3, the observations of Morrow (1977b) and the observations detailed in Chapter 7 (Table 7.2) suggest that, for adults at least, this species is also oligophagous for species of *Eucalyptus*. Unfortunately, determination of the performance of Tasmanian *G. tasmanicus* on *E. perriniana* and *E. pauciflora* (the eucalypts from which Morrow (1977b) collected *G. tasmanicus*) was not possible due to the unavailability of these *Eucalyptus* species. Thus, comparison of possible regional differences in host specificity of *G. tasmanicus* are not possible. Overall, *G. tasmanicus* was found to exhibit maximal performance on eucalypts belonging to the ash group, while performance was worst on peppermint eucalypts (e.g. *E. pulchella* and *E. nitida*). *E. tenuiramis* would appear to be an exception.

Survival of *A. obscuricornis* and *G. tasmanicus* nymphs beyond the second instar was the

most important determinant of the number of adults successfully eclosing on a given eucalypt. This instar is the first to procure nourishment from the host plant (see Chapter 5) and is thus the stage probably most influenced by eucalypt suitability. Were ovipositing females to choose hosts which optimised the survival of their offspring (Jaenike 1978), their selection mechanisms should favour plants most likely to enhance the survival prospects of this particular stadium, as immature survival is invariably very high once this stage is passed. Problems concerning the determination of an insect's host specificity (Cullen 1989) might be reduced were critical developmental stages such as this to be identified and given preferential investigation. Scriber and Slansky (1981) also suggest that experiments to determine food quality should utilise early instars

A primary aim of these performance studies was to gain some insights into the possible host specificities of the two species under consideration. It is an assumption of such investigations that those hosts which are most suitable for an insect's survival and fecundity are likely to be the same species upon which most individuals are found in nature; given their presence within particular habitats and providing that other factors, be they abiotic and/or biotic, are not limiting. Thus, one might expect that species such as *E. delegatensis*, *E. obliqua*, *E. tenuiramis*, *E. pulchella* and *E. regnans* should be favoured by *A. obscuricornis*, whilst, *G. tasmanicus* should be specific for *E. delegatensis* and *E. regnans* under natural conditions. Studies relevant to these questions are detailed in Chapter 7.

6.4ii. Effect of Nutrients, Secondary Plant Compounds and Physical Factors upon the Host Specificity of *Amorbus obscuricornis* and *Gelonus tasmanicus*.

That chemical and/or physical plant factors are important in the host specificity of these insects is clearly demonstrated by the performance data collected during these studies. Much additional study is, however, required concerning the chemical factors which influence host selection in these species before any comment upon the relative significance of one or other factor/s can be made. The findings presented should only be viewed as preliminary given the described methodology. The initial data could suggest that the concentration of primary substances (particularly nitrogen) circulating in the phloem and the shoot water content of eucalypts may be important factors influencing host plant performance in *A. obsciricornis*, however, such generalisations concerning their effect on *G. tasmanicus* are not possible. Kooi *et al.* (1991) found that the suitability of host plants to the oligophagous *Yponomeuta padellus* L. (Lepidoptera: Yponomeutidae) was most influenced by seasonal changes in nitrogen content rather than

sorbitol (a secondary plant compound). The present work only considered total nitrogen and carbon and did not differentiate the compounds with which these elements were associated. For example, was the carbon present mainly in cell wall polysaccharides or as photosynthetic sugars. Similarly, the form of the nitrogen compounds, i.e. whether amino acids, phenols or other compounds, was not determined. Miles *et al.* (1982b), however, reported that the phenolic content of *E. camaldulensis* shoots varied inversely with nitrogen content. Thus, those eucalypt species which were high in total nitrogen might be expected to be relatively low on phenolic compounds. Given the highly diverse nature of the essential oils of the eucalypts studied (Boland *et al.* 1991; Li 1993), it would not be surprising to find that the diversity of other secondary compounds also varied greatly between species. Such differences could have significant implications for the host plant performance and specificity of *A. obscuricornis* and *G. tasmanicus*.

The availability of shoots was one notable physical plant attribute that was observed to have a significant effect on adult performance. The number of shoots produced by the different *Eucalyptus* species had a significant influence upon the survival and performance of immature and adult *A. obscuricornis* (pers. obs.). For example, *E. coccifera* and *E. tenuiramis* produce opposite juvenile leaves and thus two shoots per axil as opposed to the one shoot per leaf axil in species which produce alternate foliage in the juvenile stage such as *E. delegatensis* and *E. regnans*. On such species there is a greater availability of shoots which appeared to enhance the survival of nymphs. Competition between developing nymphs in trials may have heightened this effect, especially on *E. regnans* and *E. delegatensis*. For example, the large numbers of eggs which were laid by females confined to *E. delegatensis* lead to increased competition between developing nymphs for available shoots. It was observed that in such cages nymphal mortality was very high due to some nymphs being unable to feed. On such trees shoot production became noticeably suppressed subsequently, thus reducing the quality of feeding sites for remaining nymphs. That this effect may not completely explain the results observed between host species is evinced by the fact that nymphs reared on *E. regnans* were significantly lighter than those reared on *E. delegatensis* despite many more eggs (and potential nymphs) being laid on the latter species. No-choice performance results may suggest that reproductive adults perform better on trees high in sugars (carbon), whilst, growing nymphs develop into larger adults on eucalypts with high nitrogen and water contents and/or many available shoots. The size of each eucalypt's shoots was another significant factor influencing nymphal development (pers. obs.). For example, species such as *E. globulus* (Symphyomyrtus) typically produce shoots with larger diameters, particularly in the

juvenile stage. Such shoots are often larger than many *Eucalyptus* (Monocalyptus) species. As mentioned, nymphs which were successful in becoming established on *Eucalyptus* (Symphyomyrtus) species grew into larger adults. The low establishment rate of second instar nymphs on species such as *E. globulus* appeared to be influenced by the glaucous nature of the foliage and the sessile formation of the oppositely paired leaves to the stem. The thick wax covering of juvenile *Eucalyptus* (Symphyomyrtus) foliage hindered movement of young nymphs on such species, whilst leaves which are sessile and occur in opposite pairs acted as an effective barrier preventing nymphs from reaching the apical bud to commence feeding. Although these physical barriers were quite effective against small, flightless, immatures, they were somewhat less effective against the adults. Studies which investigate the importance of plant architecture on host selection by coreids are presented in Chapter 7.

Chapter 7

Selection of Eucalypts by *Amorbus obscuricornis* and *Gelonus tasmanicus*

Chapter 7

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7.1. *Introduction*

7.1i. Insect Host Plant Selection

The commonly recognised phases in host plant selection by herbivorous insects include host habitat location, host finding, host recognition, host acceptance and host suitability (Prokopy and Owens 1983). Factors affecting host recognition/acceptance and suitability are predominantly assessed by phytophagous insects following alighting, whereas, host habitat location and host finding behaviours occur whilst the herbivores are removed from the plant, e.g. in flight and/or actively searching. Host habitat location in relation to *A. obscuricornis* and *G. tasmanicus* has been considered in Chapters 4 and 5, while the significance of plant factors such as nitrogen content, secondary plant compounds and physical attributes to host suitability for *A. obscuricornis* and *G. tasmanicus* have been given some consideration in Chapter 6. It is the intention of the studies in this chapter to consider the effect of host availability in diverse habitats, host plant architecture and other factors upon the selection behaviour of *A. obscuricornis* and *G. tasmanicus*.

7.1ii. Factors Affecting Host Plant Location and Selection.

The cues insects use to locate hosts can be divided into those which function at a distance and those which operate within a few metres or less of the host (Prokopy and Owens 1983). The long distance orientation behaviour of Hemiptera in relation to their hosts has been poorly studied in comparison to selection behaviour following alighting (Backus 1988). This author considered that the stimuli which influence the orientation of sucking insects towards their host plants varied according to the taxonomic group. For example, many aphids (Sternorrhyncha) use visual cues such as colour to locate hosts, while a few utilise olfactory stimuli (see Chapman *et al.* 1981) in long range plant detection. In contrast, leaf and planthoppers (Auchenorrhyncha) have been shown to use olfactory cues to locate hosts at distance (Backus 1988). Prokopy and Owens (1983) considered that in addition to a plant's odour the gross silhouette of a potential host influences insect orientation at distance and that as the individual nears, plant spectral quality (in particular hue and intensity) dictates behaviour. These authors noted that some insects use dimensional or plant pattern characterisitcs at close range to differentiate between potential hosts or plant structures and that background composition was another major factor influencing host detection.

The abundance of specialist phytophagous insects in vegetationally diverse habitats is commonly lower than in monospecific plant communities (Root 1973; Bach 1981, 1984; Andow 1990, 1991; Abbott 1993; Coll and Bottrell 1994). Two possible explanations for this relationship have been proposed. The resource concentration theory suggests that herbivores might be less abundant in vegetationally diverse habitats because host plants are less concentrated and thus more difficult to find and easier to lose; while the natural enemies hypothesis proposes that predators are more common in diverse habitats and cause higher mortality of resident herbivores (Root 1973). Andow (1991) considered that the resource concentration theory best explained herbivore responses to polycultures, however, exceptions to this generalisation were likely given the variable responses of specific insects in diverse habitats.

Several mechanisms are proposed as underlying the resource concentration theory. Firstly, diverse habitats may present many chemical and visual stimuli which interfere with cues important in host location (Andow 1991). For example, Tahvanainen and Root (1972) found that the odours emitted by non-host plants interfered with the location and feeding behaviour of *Phyllotreta cruciferae* Goeze (Coleoptera: Chrysomelidae). These authors considered this one way in which vegetational diversity could influence phytophagous insect populations. The interference of visual stimuli arising from vegetational diversity and its influence on host location is illustrated by the work of Smith (1976). This author found that the presence of weeds amongst Brussels sprout plants decreased the number of alate *Brevicoryne brassicae* (L.) (Sternorrhyncha) attracted to the crop. The presence of the weeds was thought to reduce the extent to which the sprouts "stood out" against their background. Such mechanisms are likely to have important implications for the location of re-sprouting eucalypts in burnt out regions by phytophagous insects (see below). For example, simplification of vegetational diversity following fire may heighten the "apparency" of visual and olfactory cues produced by re-sprouting eucalypts, enabling phytophagous insects to locate them more readily. Other resource concentration mechanisms which influence the abundance of herbivores in diverse habitats are changes in host quality due to competition, the increased frequency of encounters by herbivores with non-host plant surfaces and microhabitat effects (Andow 1991).

As a corollary of the resource concentration hypothesis, Chaplin (1980) noted that "within a plant group whose members share similar secondary host plant chemistries, the only species that will be viable hosts for a specialized herbivore are those that provide the

minimal resource density necessary for the completion of nymphal development". Chaplin (1980) found that within a given habitat, *Oncopeltus fasciatus* Dallas (Lygaeidae) selected those host species which were either in high spatial abundance or provided enough resources on the one plant to support nymphal development. It was suggested that the limited ability of nymphs to withstand dessication necessitated their development in regions of high resource density so that resource exhaustion before eclosion was unlikely.

The predictability, apparency or availability of hosts to herbivores is another selection pressure affecting the population biology of phytophagous insects (Feeny 1976; Rhoades and Cates 1976; Cates 1980, 1981). Resources such as mature leaves, bark, or long-lived abundant woody perenials are both highly apparent and very predictable, whereas young rapidly flushing leaves, flowers, or ephemeral and rare annual plants are less predictable in space and time and relatively unapparent (Cates 1980). It is suggested that apparent resources often contain high concentrations of dosage dependent quantitative defenses such as tannins, resins and other digestibility-reducing substances which are thought to be primarily effective against monophagous and oligophagous herbivores (Feeny 1976; Rhoades and Cates 1976). In contrast, such defenses are considered to be less well developed in unapparent resources, although some specific digestibility-reducing substances are known (Rhoades and Cates 1976).

The successional changes that occur in plant communities over time influence the life-cycle strategies of herbivorous insects through differences in habitat permanence, complexity and resource availability and diversity (Brown 1985, 1986). Intrinsic characterisitics of insect species such as their generation time, migratory ability, overwintering stage and reproductive potential differ according to the stage of succession of their preferred vegetational community. Brown (1982) found that the range (in size and shape) of Heteroptera increased with both the successional age of the vegetational community and the structural diversity of host plants.

7.1iii. Effect of Plant Architecture and Host Quality and Quantity upon Selection.

Prestidge and McNeill (1983) noted that there is a considerable body of literature which addresses the effect of plant architecture upon the diversity of herbivore communities, but comparatively little concerning its effect on herbivore abundance. Generally, trees (architecturally complex and comparatively large) have a more diverse fauna than herbs (architecturally simple and comparatively small). Architecturally complex plants provide a wider variety of potential feeding sites and hence living space than do architecturally

simple hosts (Prestidge and McNeill 1983). The effect of plant architecture upon the diversity of phytophagous insect communities has been reviewed by Lawton (1983).

Studies which detail the effects of modifications to plant architecture and subsequent changes in insect abundance are not common. Denno and Roderick (1991) reported that mowing of some grass species resulted in a population increase of sap-feeding herbivores that normally inhabitated the upper strata of their hosts. These species were thought to have been favoured by de-thatching through increased access to exposed resources in the lower strata. These authors reported that such architectural modifications were generally associated with a reduction in planthopper and leafhopper populations. Brown *et al.* (1992) found that the abundance of selected leafhopper species varied according to grazing treatment. Some species increased in abundance after grazing while others were either not affected, decreased in abundance and/or exhibited a more complex response.

One of the most important natural processes, particularly in the Australian environment, which can significantly alter plant architecture is fire. Eucalypts are considered well adapted to fire given their ability to coppice from lignotubers and epicormic buds (Specht 1966; Yen 1989; Davies and Myerscough 1991; Wilkinson and Jennings 1993). Species of the closely related genus, *Angophora*, also possess such an ability (Auld 1987). Defoliation by fire leads to the production of regeneration that is often soft and nutritious (Yen 1989; Mushinsky and Gibson 1991) and typically of elevated nitrogen content (experimentally simulated by Landsberg 1990b); factors which may increase its attractiveness to herbivores. The mechanisms by which fire affected plants may achieve such changes are illustrated by Bryant *et al.* (1983).

Yen (1989) found that the mean number of phytophages on coppicing eucalypts was markedly higher than the number on mature trees of the same species and interestingly, he collected *Amorbus* from coppicing hosts, which were absent from the mature trees. In addition to the higher number of phytophages on coppicing eucalypts, Yen (1989) also collected comparatively fewer predators on such hosts. Consideration of the significance of these predators to the eucalypt herbivores was not investigated.

The presence of phytophagous insects themselves can also bring about significant changes to the architecture of infested hosts (Whitham and Mopper 1985; Craig *et al.* 1986; Mopper *et al.* 1991). Mopper *et al.* (1991) note that destruction of meristematic tissue is one of the most common ways in which plant architecture can be modified by herbivores.

Such damage frequently induces the development of secondary buds, thereby shifting dominance from apical to lateral meristems. Induction of such responses in plants following herbivory has been termed "compensatory growth" (McNaughton 1983). Craig *et al.* (1986) found that heavy infestations of arroyo willows by a stem-galling sawfly, *Euura* sp., prevented maturation of affected hosts. Infested hosts produced young branches which were susceptible to further galling by *Euura*. Compensatory plant growth which replaces a herbivore's resource without reciprocal benefit to the plant has been termed "resource enhancement" (Mopper *et al.* 1991). This phenomenon has been implicated in the elevated rates of herbivory that occur on eucalypts suffering from rural dieback (Landsberg 1990a).

7.2. *Materials and Methods.*

7.2i. Incidence and Relative Abundance of Coreids on *Eucalyptus* Species Under Field Conditions.

The incidence and relative abundance of *A. obscuricornis* and *G. tasmanicus* on species of *Eucalyptus* was recorded at a number of sites visited from 1993 to 1995. The sampling method involved is detailed in Chapter 2. Data from the following sites is presented: Darcy Link Road (43°21'S 146°56'E) (aerially seeded and hand planted, undamaged, regeneration); Brooks Bay (43°14'S 147°02'E) (natural regrowth following clearing, undamaged); Ridgeway (42°55'S 147°17'E) (natural regrowth damaged by slashing); the eucalypt hybrid trial referred to as "Copping" near Woodbrook Creek (42°47'S 147°44'E) (hand sown eucalypt hybrids and some natural regrowth, all undamaged); Sandy Bay (42°55'S 147°20'E) (natural regrowth damaged by slashing); the Forest Resources concession near Nugent (42°43'S 147°45'E) (natural regrowth following clearing, undamaged); Huon Road (43°03'S 147°02'E) (natural regrowth damaged by slashing) and Waterloo (43°12'S 146°58'E) (natural regrowth damaged by slashing).

Observations are summarised according to the incidence (i.e. tree infestation rate) and relative abundance of each coreid species per infested tree. The data is evaluated in this fashion as it was considered that if either coreid species exhibited specific preferences for particular *Eucalyptus* species, then such hosts should be actively sought at a given site (see Bach 1988). In addition, because the incidence and abundance of adult insects reflects non-feeding behaviours (such as mating behaviour) as well as host preference considerations (L. Barton-Browne pers. comm.), the incidence and abundance of adults and nymphs on different eucalypts will be considered separately from one another. The data is summarised using confidence intervals and analysis of variance was used to elucidate specific trends.

7.2iia. Effect of Eucalypt Architecture on Coreid Host Selection Under Natural Conditions.

The aim of this experiment was to determine whether eucalypts could be made more attractive to *A. obscuricornis* and *G. tasmanicus* by altering their architecture. An earlier pruning trial at Sandy Bay during 1993/94 and personal observations suggested that *A. obscuricornis* found damaged eucalypts, which were vigorously re-sprouting, more attractive than trees with few new shoots. In light of these observations and the findings of Yen (1989) and Mushinsky and Gibson (1991), the experimental treatments devised were intended to simulate the regeneration that occurs after fire (Figs 7.2, 7.3). The

experiment was also intended to provide evidence as to the type of specific adaptive strategy each species employs.

Two field sites were chosen where there were a number of small eucalypt saplings. The sites chosen were the Darcy Link Rd. site (Esperance) and the Forest Resources concession (near Nugent). The Darcy Link Rd. site was aerially seeded on the 16 May 1990 with both *E. obliqua* and *E. regnans* following logging (B. Scheuker pers. comm.). Because *E. obliqua* and *E. regnans* are indistinguishable until they reach about 2 m in height (C. Turnbull pers. comm.) the species at this site will be referred to as "*E. obliqua/regnans*". The seed sown at this site was also contaminated with small amounts of *E. delegatensis*. The site had been visited since 1993 and found to be a reliable site at which to collect *G. tasmanicus* and lesser numbers of *A. obscuricornis*. The Forest Resources concession site was logged in 1988 (R. Ellis pers. comm.). The area consisted of natural regrowth *E. tenuiramis, E. obliqua, E. viminalis, E. pulchella, E. amygdalina, E. ovata* and *E. globulus*. Not all seven species are naturally found in close proximity so it was necessary to choose two sub-sites consisting of 3 to 4 of the various species. The site had been occasionally visited since late 1993 and found to be a site at which *A. obscuricornis* could be collected. Only one *G. tasmanicus* was collected at the site prior to commencing this experiment.

At each site a selection of trees was labelled for use as treatment or controls. The experimental treatment entailed removal of the tree top at either 30 cm or 1 m above the ground. These two height treatments were chosen to ascertain whether nymphs preferred trees with shoots close to the ground (which may afford immatures a degree of protection/concealment by being surrounded by low vegetation) and whether the degree of tree damage had any effect on the number of shoots produced. Trees at the Darcy Link Rd. site were pruned on the 10 June 1994, while those at the Forest Resources site were pruned on the 15 June. Treatments were administered during winter to allow resprouting prior to summer 1994/95. All side branches were removed where necessary so that trees comprised a single trunk. Control trees chosen were approximately 1 m or less in height and were left intact. The trunk diameter of control and pruned trees was measured at 10 cm above ground in order to relate the amount of regrowth with the size of the trunk. All vegetation in the near vicinity of the selected trees was slashed to allow ease of access. One data logger was installed at each site to monitor environmental conditions important to plant and insect growth (see Chapter 2). Following site preparation each locality was mapped to facilitate location of treament and control trees.

The eucalypts and treatments applied at each site are detailed in Table 7.1.

Table 7.1. *Eucalyptus* species and treatments applied in the plant architecture experiments at the Darcy Link Road and Forest Resources sites.

Darcy Link Rd. (**45 trees in total**)	Forest Resources (**118 trees in total**)
12 *E. obliqua/regnans* pruned to 30 cm	7 *E. tenuiramis* pruned to 30 cm (area 1)
10 *E. obliqua/regnans* pruned to 1 m	5 *E. tenuiramis* pruned to 1 m (area 1)
10 *E. obliqua/regnans* control trees	5 *E. tenuiramis* control trees (area 1)
5 *E. delegatensis* pruned to 30 cm	7 *E. amygdalina* pruned to 30 cm (area 1)
4 *E. delegatensis* pruned to 1 m	5 *E. amygdalina* pruned to 1 m (area 1)
4 *E. delegatensis* control trees	5 *E. amygdalina* control trees (area 1)
	7 *E. ovata* pruned to 30 cm (area 1)
	5 *E. ovata* pruned to 1 m (area 1)
	5 *E. ovata* control trees (area 1)
	7 *E. obliqua* pruned to 30 cm (area 2)
	5 *E. obliqua* pruned to 1 m (area 2)
	5 *E. obliqua* control trees (area 2)
	6 *E. viminalis* pruned to 30 cm (area 2)
	5 *E. viminalis* pruned to 1 m (area 2)
	5 *E. viminalis* control trees (area 2)
	7 *E. pulchella* pruned to 30 cm (area 2)
	5 *E. pulchella* pruned to 1 m (area 2)
	5 *E. pulchella* control trees (area 2)
	7 *E. globulus* pruned to 30 cm (area 2)
	5 *E. globulus* pruned to 1 m (area 2)
	5 *E. globulus* control trees (area 2)

At the Forest Resources site, adult *A. obscuricornis* were not seen during the spring of 1994/95. This required that adult *A. obscuricornis* be collected elsewhere and liberated in the vicinity of the experimental areas. Thus, the following insects were released at the site: 14♂♂, 11♀♀ (area 1) and 14♂♂, 13♀♀ (area 2) (1 November); 7♂♂, 12♀♀ (area 1) and 11♂♂, 5♀♀ (area 2) (23 November); 4♂♂, 1♀ (area 2) (6 December).

Pruned trees were examined on the 11 October and 18 November 1994 to count the number of epicormic buds. At this time the length of the longest shoot was also measured. Enumeration of the number of emerging shoots on treatment eucalypts ceased when the numbers present was too great to count (i.e. approximately > than 60 shoots per tree). Shoot samples from each species of eucalypt for both pruned and control trees, were taken for water, N and C analysis (see Chapter 2 for details) on the 28 November 1994, 17 January and 11 April 1995. A bush fire damaged a number of study trees at Forest Resources' area 2 on the 14 and 15 December 1994. The regrowth from fire damaged eucalypt species was also analysed for water, N and C. In addition, leaf toughness of treatment and control trees was measured on the 10 January 1995 as per the

methodology described in Chapter 2. Trees were sampled for coreids from 19 August 1994 until 13 April 1995 at regular intervals. Insects found on treatment and control trees were left undisturbed for the duration of the experiment. Individuals remaining on the same tree were re-counted at each sampling. It was considered that such insects had made a "choice" not to try and locate another host, thus, they were viewed as having positively selected that particular tree. The incidence of adults and nymphs on control and pruned trees was analysed separately using analysis of variance.

7.2iib. Effect of Eucalypt Architecture on Host Selection by Second Instar Coreid Nymphs.

The aim of this experiment was to determine whether eucalypt architecture could influence the host plant selection of second instar coreid nymphs and was intended to supplement the main field-based experiment (section 7.2iia). Second instar nymphs were used because this is the stage that commences feeding (see findings in Chapters 5 and 6) and thus, selection behaviour is likely to be most discriminatory. The experiment was conducted in the glasshouse using five "host selection arenas" (Fig. 7.3). Each arena consisted of two eucalypts; one of which had been cut back to a height of 10 cm and allowed to re-sprout and the other which had not been pruned. Eucalypts were pruned to a height of 10 cm some months before conducting this experiment to allow vigorous re-sprouting to occur. The arenas prepared comprised:

- 2 arenas each with one 24 month old *E. nitens* (re-sprouting) and one *E. nitens* (normal) tree,
- 3 arenas each with one 24 month old *E. regnans* (re-sprouting) and one *E. nitens* (normal) tree.

Trees were grown in eucalypt potting mix (detailed in Chapter 2) contained in large plastic tubs. The surface of the potting mix was covered with coarse river sand to allow easy location of nymphs. The stems of the trees in each arena were horizontally separated by 24.0 to 29.0 cm. In the case of *E. regnans*, there was approximately 40.0 to 54.0 cm of stem on the normal trees before the first leaf pedicle, while on re-sprouting trees the first leaf pedicle was at soil level. Normal *E. nitens* trees had approximately 55.0 to 63.0 cm of stem before the first leaf pedicle, while the re-sprouting trees had 0 to 3.0 cm of stem before the first leaf pedicle.

Recently ecdysed second instar nymphs of both species were obtained from mass rearing cultures (details in Chapter 2) maintained in the glasshouse. Nymphs were allowed to settle for approximately 2 hours in a small plastic container prior to commencing an

assay. Four nymphs were used per assay and were only used once. At the commencement of an assay the container with nymphs was gently placed mid-way between the trees and the lid removed. Nymphs were then allowed to leave the container and wander around the arena freely. The location of the nymphs after 24 hr was recorded. The number of nymphs on the re-sprouting and normal trees, and the arena (no selection), was recorded. The nymphs located on eucalypts were recorded as either "feeding" or "walking". Shoots which were damaged by feeding nymphs in previous trials were removed so that individuals in later assays would not be influenced in their choice of feeding site. Results were analysed by analysis of variance.

Figs 7.1-7.3. Photographs of: **(7.1)** eucalypts re-sprouting after a bush fire at the Forest Resources site 28 March 1995; **(7.2)** *E. viminalis* re-sprouting after fire, Forest Resources site 28 March 1995; **(7.3)** a host selection arena using a re-sprouting (left) and a normal (right) *E. regnans*.

7.3. *Results.*

7.3i. Incidence and Relative Abundance of Coreids on *Eucalyptus* Species Under Field Conditions.

The incidence of the two coreid species differed according to eucalypt group, i.e. ash, gum or peppermint. For example, *A. obscuricornis* was collected from eucalypts belonging to all of these groups, while *G. tasmanicus* was generally collected only on ashes and gums (Table 7.2). In only one instance was *G. tasmanicus* collected from a peppermint species, this being *E. amygdalina*. Both species could be found on natural eucalypt hybrids in the field. Indeed, at the Huon Road site the highest abundance of *A. obscuricornis* for all sites visited was recorded on a hybrid of *E. tenuiramis* x *E. amygdalina*. The only hybrids *G. tasmanicus* was found on were of gum species. Eucalypt and other plant hybrids have been shown to be more susceptible to attack by insects and fungal pathogens than pure hosts (Whitham 1989; Dungey and Potts 1994; Dungey *et al.* 1994; H. Dungey pers. comm.).

Table 7.2. *Eucalyptus* host records for *Amorbus obscuricornis* and *Gelonus tasmanicus* collected from around Tasmania from 1992 to 1995. Common species names (taken from Naughton 1995) given in parentheses. (N.B. *E. nitens* is an introduced plantation species.)

A. obscuricornis	*G. tasmanicus*
E. obliqua (Browntop stringybark)†	*E. obliqua* (Browntop stringybark)†
E. regnans (Swamp or stringy gum)†	*E. regnans* (Swamp or stringy gum)†
E. delegatensis (Whitetop stringybark)†	*E. delegatensis* (Whitetop stringybark)†
E. nitens (Shining gum)*	*E. nitens* (Shining gum)
E. viminalis (White gum)	*E. viminalis* (White gum)
E. ovata (Swamp or Black gum)	*E. ovata* (Swamp or Black gum)
E. subcrenulata (Alpine yellow gum)	*E. subcrenulata* (Alpine yellow gum)
E. globulus (Tasmanian blue gum)	*E. globulus* (Tasmanian blue gum)
E. amygdalina (Black peppermint)	*E. amygdalina* (Black peppermint)*
E. pulchella (White peppermint)	*E. globulus* x *E. viminalis*
E. nitida (Smithton peppermint)	*E. globulus* x *E. ovata*
E. risdonii (Risdon peppermint)	
E. tenuiramis (Silver peppermint)	
E. amygdalina x *E. risdonii*	
E. tenuiramis x *E. amygdalina*	
E. globulus x *E. viminalis*	

† all belong to the "ash" group of eucalypts.
* one record.

Table 7.3 summarizes the host plant observations made during field surveys from 1993 to 1995. Confidence intervals are presented in Figs 7.4-7.11 while results of analyses are presented in Table 7.4. *A. obscuricornis* was found at all the sites visited and had the highest incidence on *E. tenuiramis* x *E. amygdalina*, *E. risdonii* x *E. amygdalina*, *E. risdonii* and *E. obliqua*/*E. regnans* and the highest abundance on *E. tenuiramis* x *E. amygdalina*, *E. risdonii*, *E. pulchella*, *E. obliqua* and *E. viminalis*. Analysis of variance revealed significant differences between tree infestation rate by *A. obscuricornis* according to site and *Eucalyptus* species but no significant differences between infestation rates of adults and nymphs (Figs 7.4, 7.5 and Table 7.4). The interaction between site and eucalypt was not statistically significant. It should be noted that the number of trees infested with coreids was generally low, typically less than 1 in 10 trees had a bug.

The number of *Amorbus* per infested tree at each site and for each *Eucalyptus* species were significantly different, however, there were no significant differences between the number of adults or nymphs per infested tree (Figs 7.6, 7.7 and Table 7.4). The number of *Amorbus* per infested tree was not affected by any interaction between site and *Eucalyptus* species. These findings indicate that *A. obscuricornis* was no more abundant at sites where there were "preferred" *Eucalyptus* species than those where such eucalypts were absent.

Regression of the number of *Eucalyptus* species per site against tree infestation rate by *A. obscuricornis* did not produce a significant correlation between these two factors. This suggests that sites vegetated with one or two *Eucalyptus* species did not necessarily have a greater number of trees infested with *Amorbus*, even when the tree species were suitable for growth and development (from Chapter 6). In addition, there was no correlation between the abundance of a *Eucalyptus* species at a site and the number of *Amorbus* per infested tree.

These results have shown that the abundance of *A. obscuricornis* at a particular site is not exclusively predetermined by the available *Eucalyptus* species. Thus, other factors must influence the incidence and abundance of this species at a particular site; one such factor could be plant architecture. For example, at the Huon Rd. site there were many trees of a suitable species, namely *E. tenuiramis*, which were re-sprouting after having been slashed by local authorities because of their proximity to power lines (see Fig. 7.12). These trees had obviously been continually slashed over a number of seasons because they comprised numerous branches originating from old trunks. Similarly, Sandy Bay, Waterloo and

Ridgeway sites were reasonably infested with *Amorbus* due to the presence of re-sprouting eucalypts which had been damaged by slashing. At the Ridgeway site the comparatively high infestation rate of the few *E. obliqua* present does not reflect preferential selection for this species. At this site one particular tree was found to be regularly infested with *Amorbus* suggesting that either the modified architecture of the tree, presence of feeding wounds (pers. obs) and/or mates may have increased the attractiveness of this particular host.

Of the sites visited, the incidence of *G. tasmanicus* was highest at Darcy Link Rd. followed by the Waterloo site (see Figs 7.8, 7.13). The abundance of *G. tasmanicus* was also highest at these sites with *E. nitens*, *E. obliqua/E. regnans* and *E. delegatensis* accomodating the greatest numbers of individuals. The absence of *G. tasmanicus* from the Huon Rd. site and its comparatively low abundance at most other sites (see Table 7.2) limited possible analyses to one-way ANOVA's. Such analyses exclude to possibility of examining interactions between factors. Analysis of variance revealed a significant difference between tree infestation rate according to site and *Eucalyptus* species, but not according to stage of development, i.e. between adults and nymphs (Table 7.4). The highly significant difference between the various *Eucalyptus* species (Fig. 7.9) may simply reflect differences in infestation rate between sites, given that collections at a few sites (i.e. Darcy Link Rd. and Brooks Bay) which had a restricted range of eucalypt species, dominated total *Gelonus* collections. There were also significant differences between the number of *Gelonus* per infested tree according to site and *Eucalyptus* species (Figs 7.10, 7.11) but not according to stage of development. Again, differences in abundance according to eucalypt probably reflect differences due to site; for example sites vegetated predominantly with ashes and gums and very few or no peppermints were often inhabited by *G. tasmanicus*.

Regression analyses of tree infestation rate revealed that the rate of infestation by this species was not influenced by eucalypt abundance, i.e. sites with one species were just as likely to have the same number of trees infested with *Gelonus* as were those with more than one species. There was a very slight but statistically significant relationship between the abundance of this species and the relative abundance of different *Eucalyptus* species at any particular site (regression equation $y = 0.35 + 0.78x$, $r^2 = 0.03$ where $F_{1, 318} = 10.52$, $p = 0.001$). Curiously, it was found that as the number of *Eucalyptus* species at a site decreased the abundance of *G. tasmanicus* also decreased. The significance of this effect would require further investigation, given that a number of the sites used in this

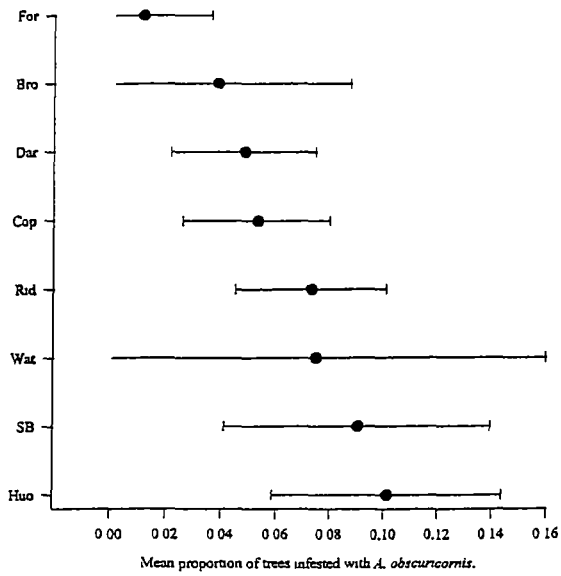
work were solely vegetated with eucalypts that were not highly preferred by *G. tasmanicus*, e.g. Huon Rd. was predominantly vegetated by *E. tenuiramis*. For example, it would have been useful to have obtained infestation and abundance data for sites vegetated solely by gum species. These findings indicate that the factors which influence host selection in *G. tasmanicus* are different from those used by *A. obscuricornis*. For example, selection of eucalypt hosts by *G. tasmanicus* would not appear to be as strongly influenced by their growth phenology/architecture as in *A. obscuricornis*. Thus, some other as yet unknown factor/s (e.g. secondary plant chemistry) must influence host selection in *Gelonus*.

Table 7.3. Proportion of trees infested with adults and nymphs of *Amorbus obscuricornis* and *Gelonus tasmanicus* according to site and the relative abundance of each species on infested trees of different *Eucalyptus* species. Observations presented as means ± se. Records summarise collections at selected sites in southern Tasmania during the period 1993 to 1995. Approximate sampling frequency of each *Eucalyptus* species at a site given in { } where the sampling frequency approximates relative abundance of a given *Eucalyptus* species at the site. Ranges given in ( ).

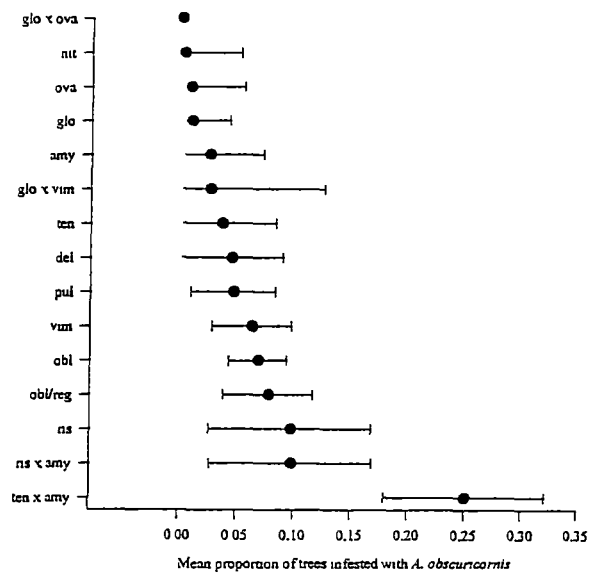
Site *Eucalyptus* sp [number of sampling occassions]	Proportion of infested trees (no. trees with coreids/total sampled)				Relative abundance (no coreids/no. infested trees)			
	Amorbus adults	*Amorbus* nymphs	*Gelonus* adults	*Gelonus* nymphs	*Amorbus* adults	*Amorbus* nymphs	*Gelonus* adults	*Gelonus* nymphs
Waterloo *E. obliqua* {1 00} [n = 3]	0.077 ± 0 031 (0.016-0 118)	0 072 ± 0.043 (0 016-0.157)	0 048 ± 0 030 (0-0.104)	0 060 ± 0 027 (0 008-0 096)	1.39 ± 0.22 (1 09-1.82)	1.53 ± 0.24 (1.25-2.00)	1 03 ± 0.53 (0-1 75)	2 27 ± 0.27 (1.73-2.59)
Brooks Bay *E. obliqua* {1 00} [n = 9]	0.054 ± 0 013 (0 006-0 118)	0 022 ± 0 014 (0-0 125)	0 022 ± 0 008 (0-0 066)	0.009 ± 0 005 (0-0 048)	1.45 ± 0 12 (1 00-2.00)	0.68 ± 0.23 (0-1 85)	1.12 ± 0.25 (0-2.04)	0.422 ± 0 22 (0-1 40)
Darcy Link Rd. *E. obliqua/regnans* {0 65} [n = 13]	0 078 ± 0.018 (0-0.238)	0.078 ± 0.028 (0-0 343)	0 148 ± 0 044 (0-0 571)	0.235 ± 0 101 (0-1.250)	1.17 ± 0.15 (0-2.25)	1.13 ± 0 26 (0-2 67)	2 08 ± 0.42 (0-4 75)	1.38 ± 0.39 (0-4 07)
E. nitens {0 28} [n = 8]	0	0 005 ± 0.005 (0-0.040)	0.266 ± 0 101 (0-0.700)	0 123 ± 0 064 (0-0.500)	0	0 13 ± 0.13 (0-1.00)	2 92 ± 0 84 (0-5.93)	1.44 ± 0 60 (0-4 36)
E. delegatensis {0 08} [n = 9]	0 062 ± 0.041 (0-0.333)	0.029 ± 0 019 (0-0.143)	0 169 ± 0 074 (0-0 667)	0 236 ± 0 093 (0-0 714)	0.20 ± 0 13 (0-1 00)	0.60 ± 0.50 (0-5 00)	1.75 ± 0.99 (0-10 00)	1 48 ± 0.74 (0-7.50)
Copping *E risdonii* {0.08} [n = 4]	0 026 ± 0 009 (0-0.037)	0 169 ± 0.107 (0-0 481)	0	0	1 40 ± 0 75 [n = 5] (0-4 00)	2 73 ± 1 18 [n = 5] (1 30-7 00)	0	0
E obliqua {0.31} [n = 4]	0 038 ± 0 018 (0-0.086)	0.102 ± 0 036 (0 007-0.160)	0 037 ± 0 019 (0-0 079)	0 021 ± 0 012 (0-0 047)	1.00 ± 0 35 (0-1.50)	1.56 ± 0 17 (1.25-2 00)	1.86 ± 0.71 (0-3.46)	1 46 ± 0 85 (0-3 00)
E risdonii x *E amygdalina* {0.10} [n = 4]	0.020 ± 0 012 (0-0 050)	0.176 ± 0.049 (0.029-0 242)	0	0	0.63 ± 0 26 [n = 5] (0-0 26)	1 67 ± 0 20 [n = 5] (1.00-2 12)	0	0
E. globulus x *E viminalis* {0 06} [n = 2]	0	0.053 (0-0.105)	0	0 111 (0-0.222)	0	1.25 ± 1 25 (0-2 50)	0	0 50 ± 0.50 (0-1 00)
E. globulus x *E ovata* {0 03} [n = 3]	0	0	0 019 ± 0 010 (0-0.020)	0 013 ± 0 013 (0-0 039)	0	0	1 33 ± 0.88 (0-3.00)	0 33 ± 0.33 (0-1.00)
E ovata {0 08} [n = 4]	0 007 ± 0.007 (0-0 029)	0.024 ± 0 017 (0-0 071)	0 013 ± 0 009 (0-0 039)	0 087 ± 0 078 (0-0.321)	0 25 ± 0 25 (0-1.00)	0.63 ± 0 38 (0-1.50)	1 25 ± 0.75 (0-3 00)	2.33 ± 1 45 (0-6 00)
E. amygdalina {0.21} [n = 4]	0.016 ± 0 012 (0-0 049)	0 062 ± 0 032 (0-0.131)	0	0	0 80 ± 0 37 [n = 5] (0-2 00)	1.35 ± 0 45 [n = 5] 0-2.75)	0	0
E. viminalis {0 01} [n = 2]	0	0 250 (0-0 500)	0	0	0	1 00 (0-2 00)	0	0
E. globulus {0 12} [n = 3]	0	0	0	0 016 ± 0 016 (0-0 049)	0	0	0	0 50 ± 0 50 (0-1.50)

Table 7.3 continued.

Site *Eucalyptus* sp. [number of sampling occassions]	Proportion of infested trees (no trees with coreids/total sampled)				Relative abundance (no coreids/no. infested trees)			
	Amorbus adults	*Amorbus* nymphs	*Gelonus* adults	*Gelonus* nymphs	*Amorbus* adults	*Amorbus* nymphs	*Gelonus* adults	*Gelonus* nymphs
Huon Rd. *E. tenuiramis* {0 98} [n = 4]	0 043 ± 0.016 (0 007-0.084)	0 064 ± 0 038 (0-0 146)	0	0	1 59 ± 0 37 (1.00-2.54)	0.92 ± 0 53 (0-1 94)	0	0
E. tenuiramis x *E. amygdalina* {0 01} [n = 4]	0.125 ± 0.125 (0-0.500)	0.375 ± 0.239 (0-1 000)	0	0	3 75 ± 3.75 (0-15 00)	4.75 ± 2.81 (0-11.00)	0	0
E. obliqua {0 01} [n = 4]	0	0	0	0	0	0	0	0
Ridgeway *E pulchella* {0.36} [n = 7]	0.054 ± 0 015 (0-0 125)	0.071 ± 0 034 (0-0 227)	0	0	1 68 ± 0 44 (0-3.17)	1 62 ± 0 71 (0-4.59)	0	0
E viminalis {0.57} [n= 7]	0.065 ± 0.015 (0-0 105)	0 041 ± 0 020 (0-0.143)	0 004 ± 0 003 (0-0 019)	0.002 ± 0 002 (0-0 011)	2 06 ± 0.50 (0-4.00)	1 50 ± 0 62 (0-3 53)	0 79 ± 0.64 (0-4.50)	0 143 ± 0 143 (0-1.00)
E. obliqua {0 05} [n = 7]	0 230 ± 0.072 (0-0.500)	0.122 ± 0.069 (0-0 429)	0	0	3 21 ± 1 24 (0-9 00)	2.14 ± 1 13 (0-7.33)	0	0
E globulus {0.02} [n = 7]	0	0	0	0	0	0	0	0
Forest Resources *E ovata* {0.13} [n = 5]	0.005 ± 0 005 (0-0 023)	0	0	0	0.20 ± 0.20 (0-1.00)	0	0	0
E. tenuiramis {0.12} [n = 5]	0 041 ± 0.030 (0-0 157)	0 004 ± 0.004 (0-0 020)	0	0	0.66 ± 0.42 (0-2.00)	0.20 ± 0 20 (0-1 00)	0	0
E amygdalina {0.12} [n = 5]	0 013 ± 0.009 (0-0.045)	0 015 ± 0 008 (0-0.042)	0	0	0 60 ± 0 40 (0-2 00)	0 60 ± 0 25 (0-1 00)	0	0
E viminalis {0.15} [n = 5]	0	0 004 ± 0.004 (0-0 019)	0	0	0	0.20 ± 0 20 (0-1.00)	0	0
E. globulus {0 23} [n = 5]	0	0 003 ± 0 003 (0-0.013)	0	0	0	0 20 ± 0 20 (0-1 00)	0	0
E obliqua {0 10} [n = 5]	0.024 ± 0 020 (0-0 103)	0.019 ± 0 006 (0-0 033)	0.003 ± 0.003 (0-0 013)	0	0 40 ± 0 24 (0-1.00)	0.80 ± 0 20 (0-1 00)	0.20 ± 0.20 (0-1.00)	0
E. pulchella {0 15} [n = 5]	0 022 ± 0.010 (0-0 050)	0.004 ± 0 004 (0-0 020)	0	0	0 60 ± 0.25 (0-1.00)	0.20 ± 0.20 (0-1.00)	0	0
CRC grounds *E pulchella* {0 52} [n = 3]	0 060 ± 0.002 (0.056-0 064)	0.070 ± 0.050 (0-0.167)	0	0	1.22 ± 0.11 (1 00-1 33)	2 83 ± 1 92 (0-6.50)	0	0
E. globulus {0.13} [n = 3]	0 059 ± 0.030 (0-0 100)	0 053 ± 0 029 (0-0 100)	0	0.033 ± 0 033 (0-0 100)	3 67 ± 3 18 (0-10 00)	3.00 ± 2 52 (0-8.00)	0	0.67 ± 0.67 (0-2 00)
E. viminalis {0 35} [n = 3]	0.109 ± 0 015 (0 081-0.133)	0 190 ± 0 095 (0-0 300)	0 011 ± 0.011 (0-0 033)	0 022 ± 0 022 (0-0.067)	1 97 ± 0 17 (1 67-2 25)	2 52 ± 1 63 (0-5 56)	0.33 ± 0.33 (0-1 00)	0 33 ± 0.33 (0-1.00)



7.4



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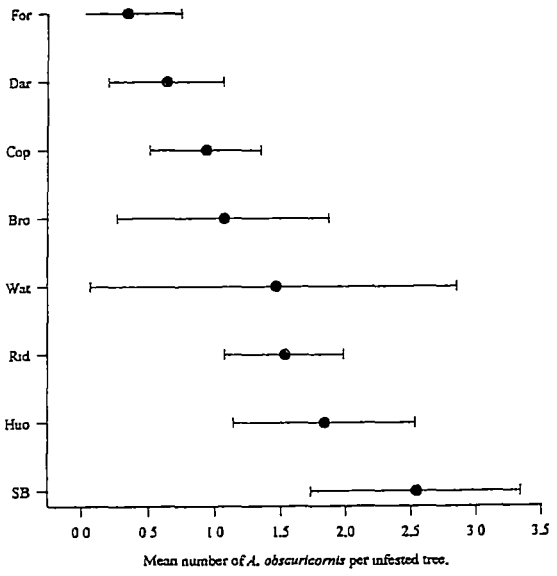

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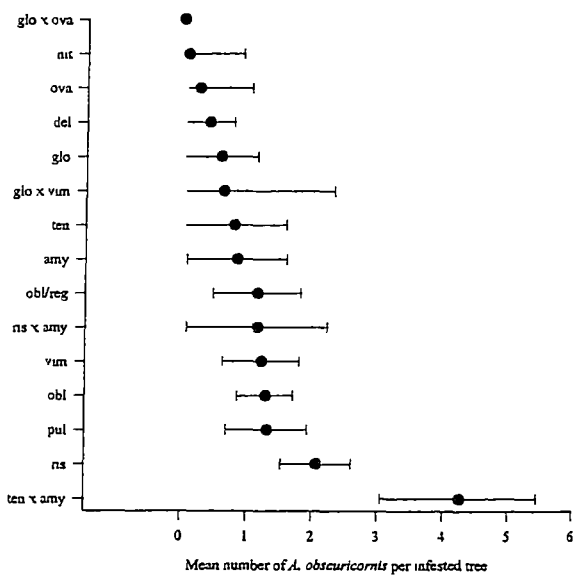
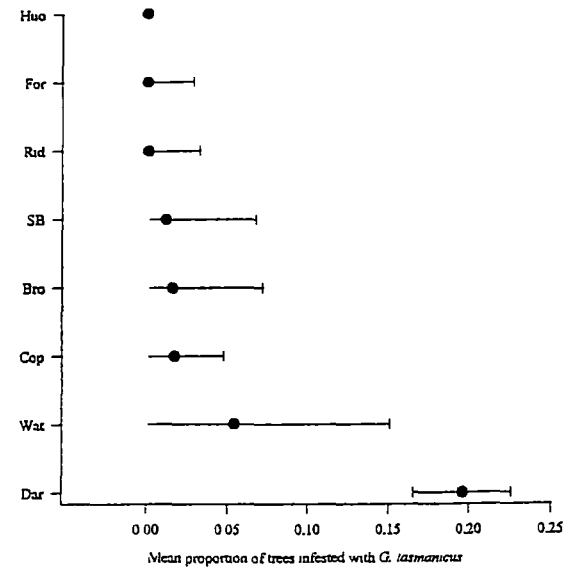
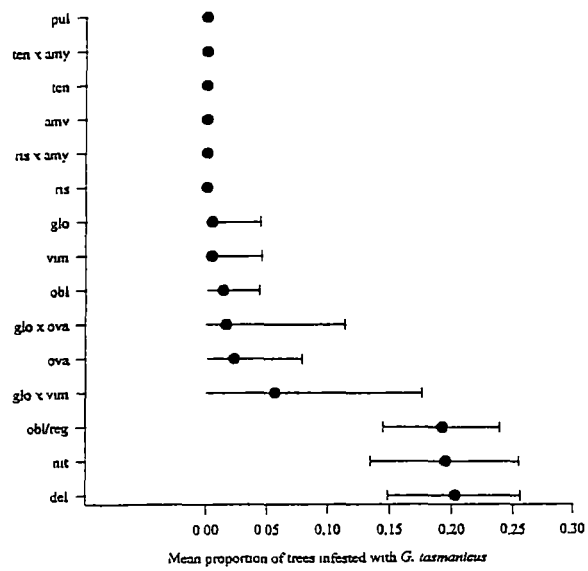


7.7

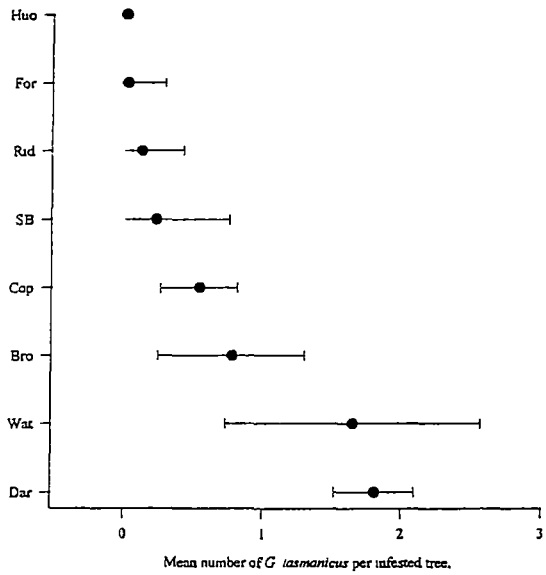
Figs 7.4-7.7. Individual 95% confidence intervals based on pooled standard deviation for mean number of: (**7.4**) trees infested with *A. obscuricornis* per site; (**7.5**) trees infested with *A. obscuricornis* according to *Eucalyptus* species for all sites; (**7.6**) *A. obscuricornis* per infested tree per site; (**7.7**) *A. obscuricornis* per infested tree according to *Eucalyptus* species for all sites. (Key: For = Forest Resources; Bro = Brooks Bay; Dar = Darcy Link Rd.; Cop = Copping; Rid = Ridgeway; Wat = Waterloo; SB = Sandy Bay; Huo = Huon Rd.; glo x ova = *E. globulus* x *E. ovata*; nit = *E. nitens*; ova = *E. ovata*; glo = *E. globulus*; amy = *E. amygdalina*; glo x vim = *E. globulus* x *E. viminalis*; ten = *E. tenuiramis*; del = *E. delegatensis*; pul = *E. pulchella*; vim = *E. viminalis*; obl = *E. obliqua*; obl/reg = *E. obliqua*/*E. regnans*; ris = *E. risdonii*; ris x amy = *E. risdonii* x *E. amygdalina*; ten x amy = *E. tenuiramis* x *E. amygdalina*. N.B. Confidence intervals for means based on less than three observations not presented.)



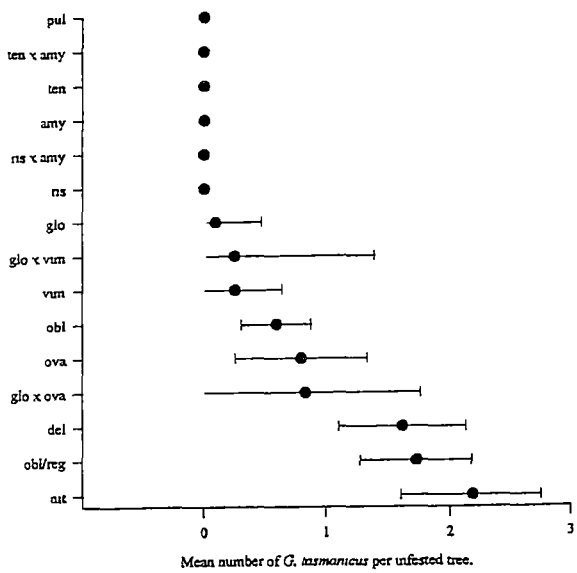
7.8



7.9



7.10



7.11

Figs 7.8-7.11. Individual 95% confidence intervals based on pooled standard deviation for mean number of: **(7.8)** trees infested with *G. tasmanicus* per site; **(7.9)** trees infested with *G. tasmanicus* according to *Eucalyptus* species for all sites; **(7.10)** *G. tasmanicus* per infested tree per site; **(7.11)** *G. tasmanicus* per infested tree according to *Eucalyptus* species for all sites. (Key: For = Forest Resources; Bro = Brooks Bay; Dar = Darcy Link Rd.; Cop = Copping; Rid = Ridgeway; Wat = Waterloo; SB = Sandy Bay; Huo = Huon Rd.; glo x ova = *E. globulus* x *E. ovata*; nit = *E. nitens*; ova = *E. ovata*; glo = *E. globulus*; amy = *E. amygdalina*; glo x vim = *E. globulus* x *E. viminalis*; ten = *E. tenuiramis*; del = *E. delegatensis*; pul = *E. pulchella*; vim = *E. viminalis*; obl = *E. obliqua*; obl/reg = *E. obliqua*/*E. regnans*; ris = *E. risdonii*; ris x amy = *E. risdonii* x *E. amygdalina*; ten x amy = *E. tenuiramis* x *E. amygdalina*. N.B. Confidence intervals for means based on less than three observations not presented.)

Table 7.4. Results of two and one-way analyses of variance of tree infestation rate and abundance per infested tree by *Amorbus obscuricornis* and *Gelonus tasmanicus*, respectively, as presented in Table 7.3.

Species, Factor	Tree infestation rate	Abundance of coreids per infested tree
A. obscuricornis		
Site	$F_{7, 193} = 2.48$, $p = 0.019$	$F_{7, 199} = 4.55$, $p < 0.001$
Eucalyptus spp.	$F_{14, 193} = 2.97$, $p < 0.001$	$F_{14, 199} = 2.97$, $p < 0.001$
Stage of development (adults versus nymphs)	$F_{1, 193} = 0.93$, $p = 0.336$	$F_{1, 199} = 0.16$, $p = 0.692$
Site * eucalypt	$F_{98, 193} = 0.11$, $p = 1.000$	$F_{98, 199} = 0.08$, $p = 1.000$
G. tasmanicus		
Site	$F_{7, 306} = 18.15$, $p < 0.001$	$F_{7, 312} = 16.42$, $p < 0.001$
Eucalyptus spp.	$F_{14, 299} = 8.84$, $p < 0.001$	$F_{14, 305} = 7.78$, $p < 0.001$
Stage of development (adults versus nymphs)	$F_{1, 312} = 0.22$, $p = 0.639$	$F_{1, 318} = 1.39$, $p = 0.239$

Figs 7.12, 7.13. Photographs of: **(7.12)** the Huon Road site 15 March 1994 showing re-sprouting *E. tenuiramis* (highlighted by arrow) beneath power lines; **(7.13)** the Darcy Link Road site 18 March 1994 showing *E. obliqua*/*E. regnans* and *E. delegatensis* regrowth (N.B. *E. delegatensis* partially hidden behind a wattle, location highlighted by arrow).

7.3iia. Effect of Eucalypt Architecture on Coreid Host Selection Under Natural Conditions.

Because of poor survival of pruned trees at the Darcy Link Road site (caused by a combination of severe frosts and waterlogging) no results will be presented for this site. Temperature, humidity and rainfall records for the Forest Resources site during this experiment are presented in Table 7.5.

Table 7.5. Weather records for the Forest Resources site from August 1994 until March 1995. Temperature and humidity records are monthly averages based on 10 minute interval records. Ranges given in parentheses.

Month	*Lomandra* sp. sward temperature (°C)	Relative humidity (%)	Air temperature (°C)	Total rainfall (mm)
Aug.	6.3 (2.7-13 3)	75.5 (32-100)	6.9 (-0 7-20.6)	117.0
Sep.	7.8 (2.9-13.0)	75.3 (35-100)	7.6 (-0.7-19.4)	12.0
Oct.	11 9 (5.8-22.0)	74.1 (18-100)	10.9 (-0.1-31.0)	42.0
Nov	13.3 (7.1-22.6)	74.3 (32-100)	11.4 (0.8-28.9)	36.4
Dec.	17.7 (9.8-27.1)	63.2 (16-100)	16.3 (3.3-35.3)	12.8
Jan.	16.6 (12 1-24.4)	83.9 (29-100)	14.7 (4.2-31.9)	181.0
Feb.	16.8 (12.1-25.8)	78.5 (21-100)	15.7 (4 8-36.8)	10.5
Mar.	14.3 (7.1-22.3)	75.7 (43-100)	12.8 (1.1-27)	8 5

• Eucalypt regrowth (Figs 7.14-7.17, 7.18-7.21). Pruning induced the appearance of regrowth which closely resembled that produced by eucalypts damaged by fire. Table 7.6 summarises the phenology of this regrowth as at the 11 October and the 18 November 1994. The control trees at this site were recorded as "flushing", i.e. producing new seasons growth, during this period. Analysis of variance of data collected on the 11 October revealed that trees of all seven species which had been pruned back to 30 cm above the ground had significantly more buds per cm of height than those pruned back to 1 m above the ground ($F_{1, 69} = 4.40$, $p = 0.04$). At the time of counting there were no significant differences in the number of buds produced by different eucalypts ($F_{6, 69} = 1.90$, $p = 0.094$). There was no interaction between pruning treatment and *Eucalyptus* species in the number of buds produced per cm ($F_{6, 69} = 0.78$, $p = 0.587$). A similar analysis of the length of shoots produced by pruned trees found no difference between those pruned back to 30 cm compared to those pruned to 1 m above the ground ($F_{1, 60} =$

2.03, p = 0.159). The statistical significance of the results concerning shoot length of pruned trees of different *Eucalyptus* species was just outside the 5% significance level ($F_{6, 60}$ = 2.24, p = 0.052). Of the seven species, *E. viminalis* had the longest shoots at this time while *E. ovata* had the shortest regrowth. The large number of developing buds on pruned eucalypts observed on the 18 November prevented full enumeration, thus, this data can not be statistically analysed. However, analysis of the data collected concerning length of the longest shoot was analysed and found to show no significant difference between the length of shoots in the two treatment groups ($F_{1, 69}$ = 0.08, p = 0.773). The individual *Eucalyptus* species exhibited very different shoot lengths at this time ($F_{6, 69}$ = 5.36, p < 0.001). *E. viminalis* was again observed to have the longest shoots while *E. ovata* and *E. amygdalina* had the shortest shoots, respectively.

A significant problem at the Forest Resources site, especially in area 1, was the continual removal of developing buds and shoots by wallabies (Table 7.6). The wallaby species concerned was found to be the Bennett's wallaby, *Macropus rufogriseus* (pers. obs.) Eucalypts such as *E. amygdalina* and *E. ovata* were so heavily and repeatedly grazed that pruned trees often remained completely devoid of all foliage. Such trees were also used as "scent posts" to mark territories through being sprayed with urine and rubbed against the wallaby's chest. Spraying part of the site perimeter with D-Ter® Animal and Bird Repellent (soluble powder) failed to protect these trees from such damage.

Data concerning the compositional analyses undertaken on shoots of pruned, control and fire damaged trees are presented in Table 7.7. Compositional analyses of this regrowth revealed that the shoots produced by pruned and fire damaged eucalypts had higher water contents than those produced by the un-pruned (control) trees (28/11/94, $F_{1, 12}$ = 19.99, p = 0.001; 17/1/95, $F_{2, 16}$ = 6.65, p = 0.008; 11/4/95, $F_{2, 16}$ = 11.33, p = 0.001). In most instances the water contents of fire damaged trees were slightly higher than those of pruned treatment trees. The higher water contents of shoots from re-sprouting trees was indicative of their higher nutrient levels. In all but two instances (namely *E. ovata* and *E. viminalis* sampled on the 17/1/95), shoots from pruned and fire damaged trees had lower C/N ratios than those from un-pruned trees (28/11/94, $F_{1, 12}$ = 21.45, p < 0.001; 17/1/95, $F_{2, 16}$ = 4.48, p = 0.028; 11/4/95, $F_{2, 16}$ = 12.91, p < 0.001), i.e. these shoots were higher in total nitrogen than those from control trees. Shoots from fire damaged trees generally had the lowest C/N ratios. Not surprisingly, the C/N ratio of pruned, control and fire damaged trees increased with time reflecting the decrease in foliar nitrogen content as growth ages (Table 7.7).

Figs 7.14-7.17. Photographs of: **(7.14)** pruned *E. tenuiramis* 15/7/94 with no regrowth; **(7.15)** pruned *E. viminalis* 2/8/94 with no regrowth; **(7.16)** pruned *E. tenuiramis* 11/11/94 with vigorous regrowth; **(7.17)** pruned *E. viminalis* 21/10/94 with regrowth (highlighted by arrow).

Figs 7.18-7.21. Photographs of: **(7.18)** pruned *E. ovata* 2/8/94 with no regrowth; **(7.19)** pruned *E. obliqua* 2/8/94 with no regrowth; **(7.20)** pruned *E. ovata* 11/11/94 with vigorous regrowth (highlighted by arrow); **(7.21)** pruned *E. obliqua* 21/10/94 with regrowth (highlighted by arrow).

Table 7.6. Regrowth phenology of pruned eucalypts at the Forest Resources site, near Nugent Results presented as means ± se. Ranges given in parentheses. Number of epicormic buds presented as number per cm of tree height. (N.B. Where there were too many buds to enumerate trees were recorded as having "numerous" buds.)

Eucalyptus sp , treatment	Trunk diameter (mm)	First buds --	11 October 1994		18 November 1994		Number trees with wallaby grazing damage (18/11/94)
			buds cm^{-1}	longest shoot (cm)	buds cm^{-1}	longest shoot (cm)	
E. tenuiramis 30 [n = 7]	48 8 ± 9 2 [n = 5] (25 0-67.0)	27/9/94	0 57 ± 0.18 (0-1 43)	1 54 ± 0 36 [n = 6] (0 75-2.75)	0 65 ± 0.09 [n = 3] (0 47-numerous)	142 3 ± 23.1 (74 0-260 0)	3
100 [n = 5]	44 1 ± 4.2 (39 5-61 0)	as above	0 20 ± 0 05 (0 09-0 37)	2 50 ± 0 86 (0 25-5 00)	0 27 ± 0 05 (0.12-0 38)	55 4 ± 6 8 (34 0-71 0)	4
E. ovata 30 [n = 7]	58.5 ± 10 3 [n = 5] (30.5-91 0)	13/9/94	0 13 ± 0 04 (0-0 27)	1 20 ± 0 31 [n = 5] (0 50-2 25)	0.51 ± 0 06 (0 23-0.70)	89 6 ± 32 8 (17 0-253 0)	6
100 [n = 5]	72 2 ± 10.8 (36.0-101 0)	as above	0 10 ± 0 06 (0-0.30)	0 58 ± 0 22 [n = 3] (0 25-1 00)	0 34 ± 0.08 (0 11-0 54)	36 6 ± 9 2 (15 0-67.0)	2
E amygdalina 30 [n = 7]	36 3 ± 5 7 [n = 5] (25 0-58 0)	27/9/94	0 67 ± 0 22 (0.17-1 60)	1.32 ± 0 54 (0.25-4 25)	- (0 5-numerous)	99 6 ± 10 4 (60 0-127.0)	5
100 [n = 5]	49.7 ± 4.3 (37.0-62 5)	as above	0.28 ± 0 07 (0 14-0.56)	2 65 ± 0 28 (1.75-3.25)	- (0 25-numerous)	76 8 ± 6.5 (60 0-93.0)	4
E. globulus 30 [n = 7]	51.8 ± 5.4 [n = 5] (37.0-65 5)	as above	0 38 ± 0 10 (0.13-0.77)	1.29 ± 0.28 (0 50-2 50)	0 47 ± 0.05 [n = 5] (0.3-numerous)	110 9 ± 28 4 (42 0-208 0)	0
100 [n = 5]	52.5 ± 4.4 (43 5-66 0)	as above	0.27 ± 0 06 (0 11-0.48)	1.25 ± 0 26 (0 75-2 00)	numerous	131 6 ± 27.3 (42 0-205 0)	0
E. pulchella 30 [n = 7]	69.2 ± 5 9 [n = 5] (48.0-83.0)	as above	0 26 ± 0.09 (0-0 73)	1.50 ± 0 37 [n = 6] (0 75-2 50)	- (0 10-numerous)	128 0 ± 28 0 (30.0-215 0)	0
100 [n = 5]	41 2 ± 3 0 (31 0-48 0)	as above	0 26 ± 0.07 (0 08-0 42)	2 50 ± 0 71 (0 50-4 50)	- (0 07-numerous)	140 2 ± 18 6 (94 0-181 0)	0
E obliqua 30 [n = 7]	63.4 ± 7.0 [n = 5] (39 0-80.0)	13/9/94	0.33 ± 0 12 (0 07-0 87)	1 18 ± 0 43 (0 25-3 00)	- (0 37-numerous)	123 4 ± 24.6 (58.0-220 0)	1
100 [n = 5]	53.7 ± 8.1 (34 0-71.5)	as above	0 26 ± 0 09 (0 01-0 50)	1 00 ± 0 21 (0 25-1.50)	- (0 03-numerous)	121 0 ± 26 2 (23 0-175.0)	0
E viminalis 30 [n = 6]	59 1 ± 11 5 [n = 5] (33.0-92.5)	as above	0 42 ± 0 20 (0-1 03)	3 25 ± 1.23 [n = 3] (1 25-5 50)	0 20 ± 0 02 [n = 3] (0 17-numerous)	158 2 ± 35.6 (50 0-299 0)	2
100 [n = 5]	59 7 ± 10.7 (20 0-80.0)	as above	0 36 ± 0 07 (0.14-0.55)	1 95 ± 0 44 (0 75-3 25)	numerous	257 0 ± 35.5 (123 0-323 0)	0

Table 7.7. Water, nitrogen and carbon contents, and the C/N ratio, of eucalypt shoots from pruned trees at the Forest Resources site during the eucalypt architecture experiment of 1994/95. Elements are given as total percentage composition.

Eucalyptus sp., treatment	28 November 1994				17 January 1995				11 April 1995			
	% water	% nitrogen	% carbon	C/N ratio	% water	% nitrogen	% carbon	C/N ratio	% water	% nitrogen	% carbon	C/N ratio
E tenuiramis												
pruned	71 0	2 9	48 9	17 0 : 1	72 9	3 3	50.2	15.2 . 1	62 5	1.8	50 6	27.5 : 1
control	65 2	2 0	50.5	25 7 : 1	65.6	2 0	51 1	25 3 1	60 9	1 6	53.4	34 5 . 1
E. ovata												
pruned	64 8	2 2	47.0	21.4 . 1	64.3	1 3	49 0	36 8 1	58 4	1 6	50 3	32 1 . 1
control	61 7	2.2	50 1	23 1 : 1	61 3	1.9	51 3	27 0 : 1	56 9	1 4	51 6	37 0 . 1
fire	-	-	-	-	70 1	2 9	48 3	16.9 . 1	63.4	1 9	48.7	25 8 1
E. amygdalina												
pruned	65 0	2 3	48 2	20 9 : 1	61 8	1 4	49 4	34 8 . 1	57.7	1 7	49 2	28 7 1
control	59.8	1.4	49 3	36 0 . 1	58 3	1 3	49 5	37 5 1	55 2	1 1	51.1	46 9 · 1
E globulus												
pruned	67.0	2.1	47 3	22 3 1	75 3	3.9	47 3	12 0 . 1	62 6	1 8	49 4	27 3 : 1
control	60 7	1 5	47.3	31.8 : 1	65 7	1 5	48 0	31 2 1	60 3	1 6	51 1	32 1 · 1
fire	-	-	-	-	72 8	3 3	48 1	14 5 1	66 9	2 8	50 0	18 2 : 1
E. pulchella												
pruned	67 2	2 7	48.8	18 2 : 1	68 8	2 7	50 6	19 0 1	62.8	2 2	52.6	23 9 . 1
control	63 9	1 9	51 6	27.1 1	63 8	1.5	51 4	35.2 : 1	58 4	1.5	52.8	35.2 : 1
fire	-	-	-	-	71.0	2 7	48 9	17.9 1	64.4	2 8	50.6	18.3 : 1
E. obliqua												
pruned	69.2	2.3	46 8	20 8 : 1	70 4	2 7	50 7	19 1 . 1	62.7	1 7	51.4	29 7 : 1
control	61.2	1.7	51 0	32.7 1	63 9	1.5	52 1	35 7 1	56 3	1 2	53 6	43 2 . 1
fire	-	-	-	-	71 7	2 5	48 8	19 5 . 1	63 2	1 8	51.4	28 9 : 1
E vunnalis												
pruned	65 1	2 1	47 1	22.1 · 1	69 9	3.1	47.5	15 1 · 1	63 8	2 7	48.5	17 9 1
control	60.2	1 8	47 7	27 1 : 1	66 6	2 7	49 4	18 6 . 1	56.9	1 5	49 7	32 2 : 1
fire	-	-	-	-	66 9	2.5	47 8	19.2 : 1	61 3	2 0	49.7	25 5 : 1

The results of the leaf toughness studies are presented in Table 7.8. These studies revealed that the regrowth produced by pruned trees was considerably softer than the new foliage produced by control (un-pruned) trees ($F_{1, 126} = 498.28$, $p < 0.001$). In addition, there was also a significant difference in the toughness of leaves between *Eucalyptus* species ($F_{6, 126} = 51.66$, $p < 0.001$). Of the seven species tested, *E. ovata* was found to have the toughest foliage while *E. viminalis* had the softest. There was also a significant interaction between the species of eucalypt and the pruning treatment administered ($F_{1, 126} = 16.03$, $p < 0.001$). The softer nature of shoots on pruned trees reflects their higher water contents (Table 7.7).

Table 7.8. Leaf toughness (in g mm^{-2}) of pruned and un-pruned trees at the Forest Resources concession on the 10 January 1995. Results presented means ± se (n = 10 per eucalypt/treatment). Ranges given in parentheses. (N.B. pruned trees were cut back to 30 cm above soil.)

Eucalyptus spp.	Pruned trees	Control (un-pruned) trees
E. tenuiramis	412.5 ± 31.3 (301.3-657.3)	775.1 ± 41.8 (575.2-944.9)
E. ovata	768.5 ± 48.7 (536.9-986.0)	1281.8 ± 86.5 (903.8-1725.5)
E. amygdalina	342.4 ± 22.8 (246.5-451.9)	561.5 ± 20.2 (493.0-643.6)
E. globulus	306.8 ± 27.1 (150.6-410.8)	671.0 ± 26.7 (561.5-794.3)
E. pulchella	382.1 ± 26.1 (287.6-534.1)	1081.8 ± 65.2 (821.7-1369.4)
E. obliqua	386.2 ± 31.8 (260.2-602.5)	1665.2 ± 80.0 (1451.6-2136.3)
E. viminalis	317.7 ± 17.3 (246.5-410.8)	495.7 ± 26.9 (342.4-616.2)

In summary, regrowth phenology observations revealed that pruned eucalypts initiate dormant epicormic buds following the loss of their canopies. The density of shoots on re-sprouting trees was observed to much higher than on control trees (pers. obs.). Such observations agree with the findings of Davies and Myerscough (1991). Compositional studies indicate that shoots produced by eucalypts which are re-sprouting after being damaged are higher in water and nitrogen and softer than those produced by normal trees. Such shoots would therefore appear to be nutritionally superior to those produced by normal trees.

• Coreid response to pruned and control eucalypts. *A. obscuricornis* was the only species recorded on tagged trees. The number of adults and nymphs of *A. obscuricornis* on pruned and control trees is summarised in Table 7.9. Unfortunately, the apparent absence of endemic *Amorbus* populations at this site during 1994/95 meant that the infestation rate of tagged trees was generally quite low.

Analysis of variance of the incidence of adult *A. obscuricornis* revealed no significant difference between the numbers of bugs on control and pruned trees of either treatment ($F_{2, 21} = 1.79$, $p = 0.192$). This suggests that adult insects did not preferentially seek pruned trees. The slightly higher number of adults on control trees may reflect their larger canopy size. Interestingly, all but one of the adults recorded on control trees was found on *E. obliqua* (see Table 7.9); the majority of these records also came from the same particular tree. Interestingly, no *A. obscuricornis* nymphs were found on control trees; nymphs were only found on re-sprouting trees. Of the two pruning treatments, there was no significant difference between the number of nymphs on trees pruned back to 30 cm compared to those pruned back to 1 m above the ground ($F_{1, 29} = 1.09$, $p = 0.305$). In a number of instances, nymphs remained on the host where they were originally observed for the duration of their immature development, e.g. nymphs on *E. tenuiramis* and *E. globulus*. These findings suggest that although the incidence of adults on control and pruned trees was not significantly different, their oviposition behaviour may have differed markedly. The complete absence of nymphs on the control trees suggests that adults found control trees less suitable for oviposition in comparison to re-sprouting pruned trees. The regrowth phenology, compositional and leaf toughness studies revealed that pruned trees provided more shoots per unit of area of space which were nutritionally superior to shoots on control trees as well as being much softer. Thus, it would appear beneficial for females to oviposit on or near those hosts which could maximise the survival and growth of their offspring. Were this experiment to be repeated it would be useful to compare nymphal survival and development on re-sprouting and normal hosts to ascertain the relative benefit to offspring of such a choice.

Although few coreids were recorded at the site during this experiment, insects did not appear to exhibit a pronounced preference for any of the *Eucalyptus* species available although the majority of adult *A. obscuricornis* were recorded on *E. obliqua* (Table 7.7). The limited number of records available concerning relative abundances prevent statistical analysis as was originally intended.

Table 7.9. Number of *Amorbus obscuricornis* adults and nymphs on pruned and control eucalypts at the Forest Resources site. Adult insects are identified by their sex, while, immatures are identified by instar (i.e I, II, III, IV and V). Number of trees with bugs given in [ ]. (N.B. Bugs on tagged trees were not disturbed during the course of the experiment, thus, individuals which remained on the same tree were counted repeatedly depending upon the duration of their stay No insects were recorded from *E. ovata* reflecting the absence of shoots due to wallaby defoliation.)

Eucalyptus sp , treatment	11/11/94	18/11/94	25/11/94	6/12/94	20/12/94	3/1/95	17/1/95	31/1/95	14/2/95	28/2/95	14/3/95	28/3/95
E tenuiramis												
30	0	0	0	2♂♂ [1]	1♂, 2♀♀ [1]	1♂, 1II [2]	1♂, 2III [3]	1♂, 2IV [2]	2V [2]	0	1♀	0
100	0	0	0	0	1♂	1♂, 1♀ [1]	3III [1]	3IV [1]	3V [1]	0	0	0
control	0	0	0	0	0	0	0	0	0	0	0	0
E. amygdalina												
30	0	0	0	0	0	1II	0	0	0	0	0	0
100	1♂	1♂	0	0	0	0	0	0	0	0	0	0
control	0	0	1♀*	0	0	0	0	0	0	0	0	0
E. globulus												
30	0	0	0	0	1II	1II, 1IV [1]	2III, 1V [1]	1III, 1IV, 1V [1]	1♀, 1V [1]	1♀, 1V [1]	0	0
100	0	0	0	0	0	0	0	1IV	0	0	0	0
control	0	0	0	0	0	0	0	0	0	0	0	0
E. pulchella												
30	0	0	0	0	0	1II	1III	0	0	0	0	0
100	0	0	0	0	0	2II [2]	1III	1IV	1V	0	0	0
control	0	0	0	0	0	0	0	0	0	0	0	0
E obliqua												
30	0	0	0	0	1♂	1II	1IV	0	1V	1II	0	0
100	0	0	0	1♀	0	0	0	0	0	0	0	1IV
control	1♂	1♂	4♂♂ [2]	2♂♂, 2♀♀ [1]	0	0	0	0	2♂♂, 1♀† [1]	0	0	0
E. viminalis												
30	1♀	1♂, 1♀ [1]	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	1♀	0	1I	0	0
control	0	0	0	0	0	0	0	0	0	0	0	0

* female flew off just after sampling.

† tree re-sprouting after fire.

7.3iib. Effect of Eucalypt Architecture on Host Selection by Second Instar Coreid Nymphs.

The numbers of second instar nymphs of both *A. obscuricornis* and *G. tasmanicus* on re-sprouting and normal hosts and wandering around the host selection arena (no selection) after 24 hr is presented in Table 7.10. This bioassay was found to be a useful supplement to the field experiment because it enabled selection by second instar nymphs to be investigated, as well as providing some insight into the host selection behaviour of *G. tasmanicus* which was absent from the Forest Resources field site.

In the case of *A. obscuricornis* nymphs, re-sprouting *E. regnans* were chosen more often than the normal *E. regnans* trees. Such a relationship was not evident when nymphs were given a choice between re-sprouting and normal *E. nitens*. In these instances, a number of nymphs were found wandering around the arena (i.e. had not made a selection for a particular host) while even more were missing, having wandered out of the arenas. The apparent non-preference of *A. obscuricornis* for *E. nitens* may be due to nymphs either not recognising this eucalypt as a host and/or being unable to locate shoots due to the waxy nature of the plant and/or it's opposite, sessile, juvenile leaves which protect the apical bud. These observations were reflected in the statistical analysis; for example eucalypt was found to have a very significant effect on selection ($F_{1, 93} = 11.84$, $p = 0.001$), similarly differences between selection for re-sprouting and normal hosts and "no selection" were significant ($F_{2, 93} = 14.92$, $p < 0.001$). The different response of *A. obscuricornis* to re-sprouting trees of the two species is reflected in the highly significant interaction term ($F_{2, 93} = 16.90$, $p < 0.001$).

The apparent preference of *A. obscuricornis* nymphs for re-sprouting *E. regnans* could be due to the lesser distance nymphs have to walk before reaching the first potential feeding site rather than selection for presumably nutritionally superior feeding sites (see previous section), i.e. foliage began at soil level on re-sprouting trees in comparison to the normal trees (see distances given in the materials and methods section). The importance of this possibility should not detract from these findings as this factor could be vital to nymphal survival if females lay their eggs in leaf litter near the base of suitable hosts and/or should the young nymphs become detached from the tree. Given the small size of second instars and their large surface area to volume ratio, they would have comparatively few fat reserves and limited water reserves to enable extensive host searching before dying of starvation and/or dessication. The relationship between an individual's energy reserves and its searching behaviour is briefly considered in Scriber and Slansky (1981). Thus,

locating a host at ground level with many nutritious shoots would certainly favour high nymphal survival.

Second instar nymphs of *G. tasmanicus* appeared to show no particular preference for eucalypts of either architectural type or species, although there were slightly more nymphs on normal trees. It should be noted that the number of assays run for *G. tasmanicus* was fewer than those for *A. obscuricornis*, but the results suggest that these species exhibit very different host selection mechanisms. Analysis of variance revealed that *Eucalyptus* species had no significant effect upon host selection by *G. tasmanicus* ($F_{1, 36} = 0.11$, $p = 0.742$), similarly differences between selection for re-sprouting and normal hosts and "no selection" were not significant ($F_{2, 36} = 1.80$, $p = 0.180$). The similarity of selection response between *Eucalyptus* species and architectural types by this species is reflected in the non-significant interaction term ($F_{2, 36} = 0.92$, $p = 0.407$).

Table 7.10. Selection of eucalypts by second instar nymphs of *Amorbus obscuricornis* and *Gelonus tasmanicus* on the basis of their architecture. Results represent the total number of nymphs recorded in each location.

Coreid, eucalypt	Re-sprouting		Normal		Arena	Missing
	feeding	walking	feeding	walking	(no selection)	
A. obscuricornis						
E. regnans [n = 20]	23	21	8	2	17	9
E. nitens [n = 13]	2	4	1	3	15	27
G. tasmanicus						
E. regnans [n = 9]	3	6	10	3	10	4
E. nitens [n = 5]	1	1	4	3	7	4

7.4. *Discussion.*

7.4i. Selection of Eucalypts by *Amorbus obscuricornis* and *Gelonus tasmanicus*.

This chapter has investigated some of the factors affecting host selection in *A. obscuricornis* and *G. tasmanicus*. In *A. obscuricornis* it is perhaps not surprising to find that host phenology/architecture is a significant factor influencing selection, given this species preference for shoots. The regrowth phenology and foliage compositional results obtained from the pruning experiments and the subsequent attractiveness of such foliage to *Amorbus* parallel the findings reported by Landsberg (1990b). This author found that the clipping of terminal branches of *E. blakelyi* resulted in the production of regrowth which was nutritionally superior to that on nearby un-clipped trees. The regrowth produced was preferentially grazed by insects despite briefly elevated tannin levels.

Given that first instar *Amorbus* nymphs do not move far (see Chapter 5), the findings from the plant architecture experiment infer that ovispositing females preferentially deposit eggs on or near eucalypts with large numbers of suitable shoots, e.g. trees coppicing after fire and/or physical damage. Shoots of such eucalypts are typically more nutritious than those of normal eucalypts, thus females may be able to maximise their offsprings' chances of survival and eclosion by locating them near such hosts. This type of host selection parallels that reported in *Oncopeltus fasciatus* (Chaplin 1980). Second instar nymphs of *A. obscuricornis* were also found to select re-sprouting as opposed to normal hosts of preferred *Eucalyptus* species. Such selection by nymphs does not simply reflect preference considerations, but also behavioural adaptations which may assist immatures from dying should they become separated from their host following hatching (Chaplin 1980). Reliance upon location of hosts with optimal shoot growth in both the adults and nymphs lends support for the insignificant site by eucalypt interaction term and the lack of a correlation between proportion of *Eucalyptus* species and incidence or abundance (section 7.3i), i.e. insects are responding to sites not on the basis of the eucalypts present, but rather their phenology/architecture. For example, a number of adult *Amorbus* were collected from *E. globulus* at Sandy Bay during late 1994. Typically *E. globulus* is not a species from which *Amorbus* is collected, however, on this occassion the "tree" in question was a vigorously re-sprouting stump. Interestingly, the eucalypt foliage sampled by Morrow (1977b), and from which an *A. obscuricornis* was collected, was dense coppice produced as a result of slashing beneath powerlines.

The incidence of adult *Amorbus* on re-sprouting trees is also influenced by factors other than ovipositional preference. For example, re-sprouting hosts often have higher

abundances of *A. obscuricornis*, apparently because additional insects appear at such sites in order to mate and/or because there are shoots beginning to wilt which become attractive feeding sites to other individuals (pers. obs). The benefits of aggregated feeding have been considered by Ralph (1976). In the absence of coppicing hosts such congregations can occur on normal trees, some of which may have had resident *Amorbus* populations for sometime (*E. obliqua* at Ridgeway, see Fig. 7.22) thus developing an architecture appealing to this species, i.e. repeated destruction of apical shoots induces the initiation of lateral buds thereby enhancing a particular host's attractiveness to further attack.

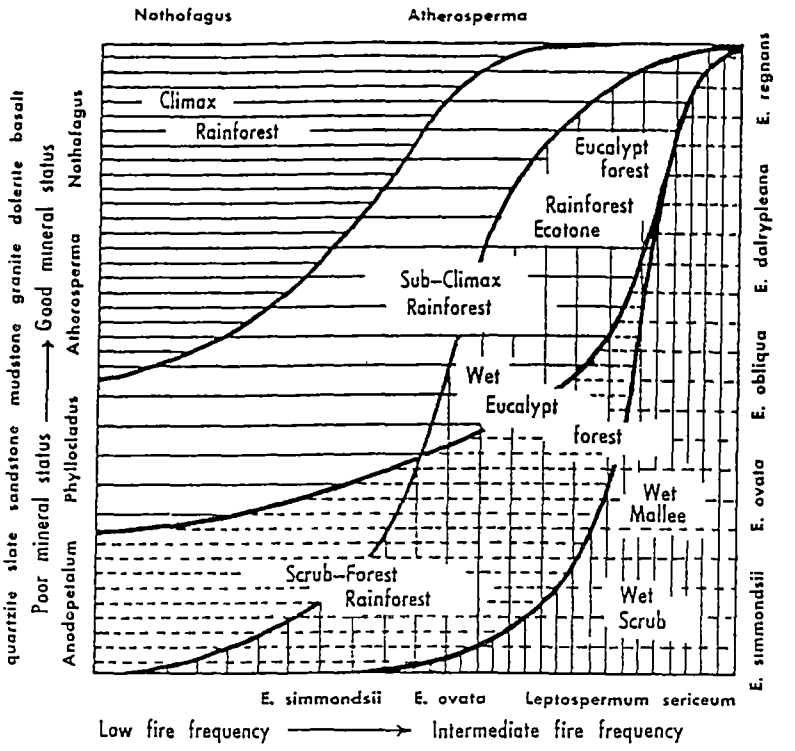
The studies reported in this chapter have not greatly enhanced understanding of the selection mechanisms which influence *G. tasmanicus* although they offer certain insights. Importantly, *G. tasmanicus* was not commonly collected from eucalypts of the peppermint group (Table 7.2), nor did their appear to be a marked preference for eucalypts based on their phenology/architecture (sections 7.3i and 7.3iib). This latter finding is supported by the species' ability to feed on numerous plant parts (pers. obs) rather than being an obligate shoot feeder. These facts suggest that host selection by *Gelonus* could be influenced by unique factors which may include plant secondary chemistry. For example, botanical recognition of eucalypts such as the peppermints could be influenced by the presence of characteristic secondary compounds such as *cis*-piperitol and piperitone (Li 1993). That this species' host selection may not be as significantly influenced by primary (nutritional) plant substances is also partially supported by the findings concerning adult performance in Chapter 6.

Fig. 7.22. Photograph of the *E. obliqua* sapling (approximately 60 cm high) at the Ridgeway site which was repeatedly infested with *A. obscuricornis* adults and nymphs. The destruction of apical shoots, due to the feeding activities of these bugs, has initiated the development of numerous laterals. Shoots wilted by *A. obscuricornis* can be recognised by the presence of manna (highlighted by arrows).

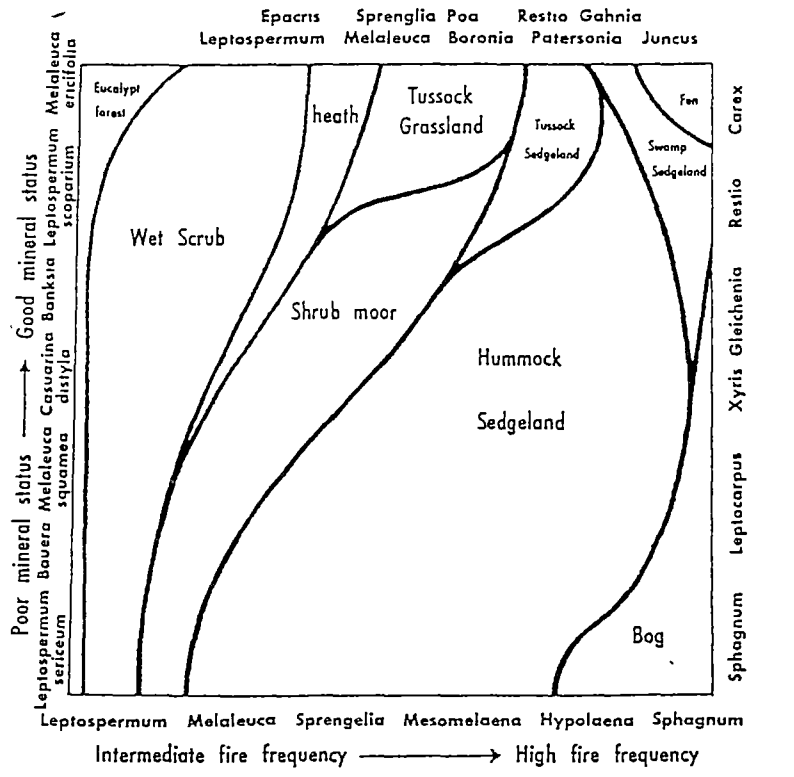
7.4ii. Adaptive Strategy of *Amorbus obscuricornis*.

The preference of *Amorbus* for *Eucalyptus* to the exclusion of other endemic plant genera indicates that this insect is adapted to mid successional habitats (*sensu* Brown 1982). Generally, eucalypt forest tends towards scrub and grassland/sedgeland with high fire frequency or rainforest under low fire frequency (Figs 7.23, 7.24). The presence of *Amorbus* in mid successional habitats supports the findings of Brown (1982), although the occurrence of fire represents a very significant difference between such communities in the United Kingdom and those in Australia. Unlike mid successional environments in the U.K., the eucalypt forests of Australia represent a disclimax community that requires the occurrence of fire to maintain dominance (see Chapter 4; Davidson *et al.* 1981; Kirkpatrick *et al.* 1988), thus, specialist eucalypt feeders such as *A. obscuricornis* must possess adaptive features that enable it to endure fire and its consequences. Of the two main types of sclerophyll forest, wet sclerophyll occurs only when the frequency of fire is low, whereas dry sclerophyll is a community that develops under intermediate fire frequency (Ashton 1981; Christensen *et al.* 1981). The ability of *A. obscuricornis* to utilise dry sclerophyll *Eucalyptus* species, as well as those of wet sclerophyll, is further evidence that the species is adapted to habitats influenced by fire.

Some species of eucalypt can produce regrowth after being damaged by fire within a very short period (Christensen *et al.* 1981; Davies and Myerscough 1991; Wilkinson and Jennings 1993). Wilkinson and Jennings (1993) noted that the intensity of the fire and the age of the eucalypts dramatically affects their regrowth potential. Thus, re-sprouting eucalypts are a temporally and spatially spasmodic resource; their availability depending upon the location of the last fire and the type of sclerophyll community burnt. The ability to locate and utilise such hosts suggests that *A. obscuricornis* retains an ability to colonise "transient resources" (after Maelzer 1977) such as those produced by re-sprouting eucalypts. Similar statements regarding the colonisation abilities of other coreids have been made by Aldrich *et al.* (1976, 1979). Given the patchy occurrence of coppicing eucalypts, a high degree of host specificity for a few *Eucalyptus* species would not be beneficial to the survival of an insect such as *A. obscuricornis* under natural conditions. The oligophagous habit of *Amorbus* would appear to enable the species to colonise re-sprouting eucalypts belonging to a number of species, thereby increasing the potential availability of suitable hosts. Such suggestions are supported by Wiklund (1974).



7.23



7.24

Figs 7.23, 7.24. Diagrams illustrating suggested ecological relationships of: (7.23) *Eucalyptus* and rainforest forms; (7.24) scrub and sedgeland forms (from Jackson 1965). (N.B. *E. simmondsii* is a synonym for *E. nitida*.)

The timing of bush fires during a year will significantly influence the degree to which *A. obscuricornis* is able to colonise re-sprouting hosts. For example, a sclerophyll community damaged by fire during late autumn would be producing the most succulent regrowth during the following spring when adult *Amorbus* are most actively seeking suitable oviposition hosts. In such instances colonisation of the re-sprouting eucalypts could be maximised. In comparison, eucalypts burnt during mid summer (as per those at the Forest Resources site) may escape much initial *Amorbus* damage as ovipositing adults are mostly absent at this time of the year. However, such regrowth would still be reasonably suitable the following spring and thus may be preferentially colonised.

Between fires, when eucalypts are not induced to coppice, *A. obscuricornis* may persist at low densities on trees which were attacked following the last fire or tree damaging event. In such instances the continual destruction of shoots would lead to secondary bud initiation (Mopper *et al.* 1991), as was seen in glasshouse colonies confined to trees for a period of many months. Trees which are thus attacked produce a canopy with characteristic "flat-top brooming" (Bashford 1992) (similar to Fig. 7.22). For a shoot feeding insect, such as *A. obscuricornis*, the production of additional shoots following herbivory would obviously be a very beneficial plant response. In such instances, *Amorbus* would appear to benefit from "resource enhancement" (Mopper *et al.* 1991) of hosts through it's feeding strategy. Alternatively, some adults may move from one habitat to another in order to locate eucalypts with abundant shoots; the abundance of which for any one area being influenced by environmental factors such as rainfall and temperature (Specht and Brouwer 1975). Maelzer (1981) considered many aphid species to be "flush" feeders because they fed preferentially on young plant tissues such as growing tips and young flower buds. It was suggested that aphids were most abundant during spring because the availability of young growing shoots of optimal quality was maximal at this time (Maelzer 1977, 1981). *Mictis profana* (F.) (Coreidae) is also thought to employ a similar survival strategy on the Australian mainland (P. McQuillan pers. comm.). That fluctuations in resource availability, and therefore habitat carrying capacity, can have significant effects on insect populations has been shown (Dempster and Pollard 1981; A. Berryman pers. comm.). The results of my studies lead me to believe that *A. obscuricornis* is also a flush feeder whose success is determined by the availability of eucalypt shoots. The ability to locate and utilise eucalypts re-sprouting after fire or other such event is the ultimate demonstration of this adaptive strategy.

Plantations of young eucalypts could be viewed as approximating fire damaged regions in

that they comprise many eucalypts producing vigorous shoots, however, the architecture of a whole sapling and that of a re-sprouting tree are notably different. For example, the work detailed herein indicates that saplings produce comparatively few shoots of lower nutritional status than are produced by re-sprouting trees. Despite the somewhat less desirable structure of such hosts, *A. obscuricornis* will still utilise plantation saplings and therefore pose a problem to Australian plantation forestry.

Chapter 8

Defensive Secretions and the Parasitoids, Parasites and Predators of *Amorbus obscuricornis* and *Gelonus tasmanicus*

Chapter 8

Defensive Secretions and the Parasitoids, Parasites and Predators of *Amorbus obscuricornis* and *Gelonus tasmanicus*

Introduction

This chapter is presented in an abbreviated format because the studies undertaken have been published in refereed journals. Thus, repetition of their contents was considered unnecessary. The publications in the back pocket of this thesis detail the work performed and the results obtained, whilst, some additional points not covered are addressed briefly below. In addition, given that these studies are somewhat outside the main topics under consideration in this thesis, it was considered that earlier inclusion might interrupt the development of the themes under discussion.

8.1. The Defensive Secretions of *Amorbus obscuricornis*, *Amorbus rubiginosus* and *Gelonus tasmanicus*.

The nymphal and adult defensive secretions of *A. obscuricornis*, *A. rubiginosus* and *G. tasmanicus* were analysed using gas chromatography-mass spectrometry (GC-MS). Of the 15 volatile aliphatic compounds identified, two have not been recorded from the Coreidae previously, namely 2-hexanone and *n*-butyl acetate. The composition of the secretions from nymphs and adults of the same species were found to differ markedly, however, nymphal secretions were qualitatively more similar across species than those of the adults. Quantitative differences between secretion compositions of adult males and females of the same species were minimal. Full details of these studies are presented in: Steinbauer, M.J. and Davies, N.W. (1995). *J. Aust. ent. Soc.* **34:** 75-78 (back pocket of this thesis).

Pasteels *et al.* (1983) considered that chemically defended insects which emit volatile, nonspecific irritants (such as those released by these coreid species) were typically long lived, large to moderate in size, were specialist herbivores (i.e. monophagous or oligophagous) which fed upon herbs and shrubs in open habitats and were aposematically coloured and often formed aggregations. Many of these features appear to be expressed in *A. obscuricornis*. For example, individuals live for approximately one year (see Chapter 4), the nymphs and adults of this species are large, the species is considered to be oligophagous (see Chapters 6 and 7) with both nymphs and adults living on eucalypt trees often in open sclerophyll forest and lastly nymphal stages II to V are aposematically

coloured. However, aposematic aggregations of *A. obscuricornis* nymphs, such as those described by Aldrich and Blum (1978), have not been seen. In contrast, *G. tasmanicus* seems to fulfil few of these criteria.

In addition to these defensive secretions, coreid males have been shown to use species specific secretions (i.e. pheromones) to attract females. The attraction of migratory females by male bugs using pheromones is suggested as an adaptation which facilitates the colonisation of successional habitats. Aldrich (1991) proposed that pheromone lures based on pest bug secretions could be used to augment and protect bug predators by influencing their behaviour. That some insects can even be attracted to the metathoracic scent gland (MTG) defensive secretions of Heteroptera has been demonstrated by Eisner *et al.* (1991).

The evaporatorium of adult *A. obscuricornis* was examined using SEM; the surface micro-structure can be seen in Fig. 3.37vi. The micro-structure resembled the "mycoid microsculpture" referred to by Carver (1990). In adult *Poecilometis longicornis* (Dallas) (Pentatomidae) this structure was considered to slow the evaporation of the secretion to "maximise its repellency" (Carver 1990). This author considered that the epithet "evaporative" was more appropriate to the "finger-like" projections of the peritreme than the mycoid surface.

8.2. The Egg Parasitoid, *Xenoencyrtus hemipterus* (Girault).

Eggs of *A. obscuricornis* and *G. tasmanicus* were found to be parasitised by the encyrtid parasitoid *X. hemipterus*. In addition, adults were parasitised and predated by a number of other organisms. Details concerning these species can be found in: Steinbauer, M.J. and Clarke, A.R. (1995). *J. Aust. ent. Soc.* **34:** 63-64 (back pocket of this thesis).

Parasitised eggs were clearly recognisable from non-parasitised eggs. Under the light microscope parasitised eggs were identified by the presence of parts of the wasp egg, namely the neck and bulb (Noyes 1988), which remain external to the host. According to Noyes (1988) eggs belonging to such species have an aeroscopic plate which aids respiration of early-instar wasp larvae by allowing the passage of atmospheric air into the host egg.

The family Encyrtidae is one of the most important groups from which biological control agents have been derived (Noyes 1988). *X. hemipterus*, itself, has been used as biological

control agent of the hemipteran pest, *Nezara viridula* L. in Hawaii (Clarke 1990). Whether *X. hemipterus* could be utilised in such a way to control damaging *A. obscuricornis* populations requires much additional study. For example, research is needed to ascertain the rate of parasitisation that occurs naturally in the field and the factors which influence this rate of egg mortality. Primarily, the host specificity of *X. hemipterus* for eggs of *A. obscuricornis* needs to be determined, given that the evidence presented in Steinbauer and Clarke (1995) shows that this coreid is only one of a number of known hosts for this wasp.

8.3. Observations of the Interactions Between Ants Foraging for Manna and *Amorbus obscuricornis*.

The production of manna (a sugar rich exudate of eucalypts) is often associated with the feeding injuries of the coreid, *A. obscuricornis*. The manna produced as a result of the injuries caused by *A. obscuricornis* is extremely attractive to ants and it is often taken right from underneath feeding bugs. Observations of a number of Tasmanian ant species feeding upon eucalypt manna suggest that this substance is an important source of carbohydrate for the ants. The possible significance of this substance to insect-plant interactions in general is considered in: Steinbauer, M.J. (1995). *J. nat. Hist.* (in press) (back pocket of this thesis).

Chapter 9

Discussion

Chapter 9

Discussion

Introduction

This thesis has considered aspects of the taxonomy, biology and ecology of three Australian coreid genera, namely *Gelonus* Stål, *Acantholybas* Breddin and *Amorbus* Dallas. In particular, it has focused on the Tasmanian species, *Amorbus obscuricornis* (Westwood) and *Gelonus tasmanicus* (Le Guillou), while the rediscovery of *Acantholybas kirkaldyi* Bergroth enabled me to undertake a taxonomic revision of this genus. Prior to this thesis almost nothing was known of these species and of that which was recorded much has been found to be incorrect. Thus, the studies detailed in the previous chapters represent the first thorough investigations undertaken on *A. obscuricornis* and *G. tasmanicus*. The significance of specific findings are considered in detail at the end of each research chapter and it is not my intention to repeat them in detail in this chapter. Rather, in concluding this work, I would like to focus on the major findings, their significance and highlight additional areas worthy of investigation.

9.1. Taxonomic Status of *Gelonus* Stål, *Acantholybas* Breddin and *Amorbus* Dallas in Tasmania.

At the start of this work there were thought to be three *Amorbus* species in Tasmania, *A. angustior* (Westwood), *A. obscuricornis* (Westwood) and *A. rubiginosus* (Guérin-Méneville) (Semmens *et al.* 1992). An informal taxonomic review, which included viewing types, studying the original descriptions, morphometric analysis, SEM and paramere studies, has led me to propose that *A. angustior* is conspecific with *A. obscuricornis*. Following a formal revision of the genus, taxonomic priority should dictate that *A. angustior* be used to refer to Tasmanian *Amorbus* species. However, for this thesis, this lead was been adopted in recognition of the fact that specimens of *A. angustior* were originally described from the Australian mainland, while Westwood's type locality for *A. obscuricornis* is Tasmania. Additionally, given that existing references use this name in relation to the Tasmanian species, it was thought appropriate to continue its use until such time as a formal revision is undertaken.

Examination of specimens of *A. rubiginosus* confirmed the unique identity of this species and provided initial support for suggesting that this insect does not occur in Tasmania, as there were no Tasmanian specimens of this species in museum collections. Field

collections confirmed the absence of this species in the state. It is suspected that *A. rubiginosus* was included in the species list prepared by Semmens *et al.* (1992) as a result of the comments of Evans (1943). Taxonomic studies also confirmed the existence of only one *Gelonus* and one *Acantholybas* species in Tasmania, i.e. *G. tasmanicus* and *A. kirkaldyi*. No evidence for a second *Gelonus* species (as per Morrow 1977b) in Tasmania was found. Clarification of the identities of the Tasmanian coreid species required significant effort to be directed towards the taxonomy of these genera (Chapter 3). Such investigations should not need to be repeated if future studies of these species in Tasmania are undertaken. This will allow research time to be dedicated to some of the topics detailed below.

9.1i. Taxonomic Status of the Genus *Amorbus*.

This genus is in need of a formal revision as work undertaken in this thesis suggests it contains a number of undescribed species (Chapter 3). Carver *et al.* (1991) considered that the genus comprised some 15 species, however, this study (and those by G.F. Gross) has identified 20 species (7 of which are new) and it is suggested that 2 or 3 more could exist. Based on the degree of maculation of the hind femora, banding of the dorsal laterotergites, body colouration and shape, I consider that the genus consists of four "species-groups". Three species, namely *A. robustus, A. biguttatus* and *Amorbus* n. sp. 5, do not closely resemble the members of any of these groups. Indeed, *A. robustus* has a number of features in common with *Mictis profana* (F.). Phylogenetic analysis could help resolve some of the evolutionary hypotheses proposed at the end of Chapter 4 and would be of great benefit to understanding the evolutionary radiation of this genus.

9.2. Biogeography of *Gelonus*, *Acantholybas* and *Amorbus*.

Study of specimens in Australian invertebrate collections enabled the mapping of genera distributions for the first time. *G. tasmanicus* was found to be restricted to south-eastern Australia, while *A. kirkaldyi* has only been collected from Tasmania. The other members of *Acantholybas*, namely *A. brunneus* (Breddin) and *A. longulus* Breddin, occur in southern Queensland/New South Wales and Indonesia, respectively (Chapter 4 and Appendix 3).

Members of the genus *Amorbus* inhabit most regions of Australia and the genus' distribution closely matches that of it's *Eucalyptus* hosts. Two regions of high *Amorbus* endemism were apparent from these distributions, namely southern New South Wales and south-west Western Australia. These regions coincide with areas of high eucalypt

endemism (Chippendale 1988) and it was this finding primarily which prompted my suggestion that the specific evolutionary radiation of *Amorbus* had followed that of the eucalypts.

The host plant records obtained from specimens in collections suggest that most *Amorbus* species are oligophagous, and that only one (*A. bispinus*) is monophagous for *Eucalyptus* species. The development of monophagy in *A. bispinus* may have been because the host eucalypt, Jarrah (*E. marginata*), grows in monospecific stands (Chippendale 1988). Based on collection records and field observations (Chapters 4, 6 and 7), *G. tasmanicus* is also considered to be oligophagous on *Eucalyptus*.

Members of the genus *Acantholybas* may not be specific for *Eucalyptus* species, given the presence of two species in countries (New Zealand and Indonesia) where eucalypts are not endemic. *A. brunneus* has been recorded from a diverse array of plants, belonging to more than one family (Woodward 1951, 1953, 1961; Wise 1958a, b; D. Cowley pers. comm.), suggesting that the species might be polyphagous. Insufficiency of host plant records for *A. kirkaldyi* and *A. longulus* prevents comment on these species.

That the distribution of appropriate eucalypt hosts may not be the only factor determining the distribution of these genera was briefly considered in Chapter 4. For example, the distributions of some *Eucalyptus* host species extended into regions where coreids known to feed on them had not been collected. Although the absence of other host eucalypts may be significant in relation to this observation, this finding could indicate that abiotic environmental factors, such as temperature and effective rainfall, may also have a bearing on the range of these insects (Jeffree and Jeffree 1994). Temperature is a major determinant of insect distributions and warrants further investigation with regards to Australian coreids.

9.3. Seasonal Phenology and Biology of *Amorbus obscuricornis* and *Gelonus tasmanicus*.

The seasonal phenology of *A. obscuricornis* and *G. tasmanicus* was described in Chapter 4. In Tasmania both species are predominantly univoltine with most activity being confined to spring and summer, however, a few early instars were observed during late summer/early autumn. These nymphs were suggested to form a dysfunctional second generation that presumably die during the proceeding winter when eucalypt shoot growth ceases and temperatures fall.

Studies detailed in Chapter 5 illustrate that overwintering *A. obscuricornis* and *G. tasmanicus* adults emerge in spring to feed, mate and oviposit. The majority of their offspring develop during summer and eclose in early autumn. Following eclosion newly emerged adults continue feeding in order to increase their fat reserves and may also mate prior to overwintering. The accumulation of fat prior to the onset of unfavourable conditions is suggested to be a physiological adaptation enabling these insects to survive months of starvation during winter. Such findings agree with studies of other Heteroptera/coreids (Solbreck 1972; Ito 1985). Although temperature and humidity were found to be important factors determining starvation longevity under artificial conditions, the temperature/moisture requirements and behaviour of adults under natural conditions is not known.

Egg developmental rate studies have provided estimates of degree-day requirements and minimum developmental threshold temperatures for both *Amorbus* and *Gelonus*. Values estimated differ markedly from those provided by Bashford (1992). The significance of fluctuating temperatures upon egg development seems a logical and important topic for future research. In addition, the placement of eggs by adult females under field conditions is another area of investigation that requires much research as no eggs were found in the field by me. The site of oviposition may have important implications for host location by early instars.

My work confirmed that nymphal development proceeds via five instars; not six as proposed by Green (1972) and Bashford (1992 *in lit.*). It was also found that first instar nymphs of *A. obscuricornis* do not require plant derived nutrients in order to ecdyse, but rather needed water which could be obtained from foliage or external sources. The first instar was also found to be relatively sedentary when resting on live foliage and thus is unlikely to be the "dispersive" stage as suggested by Bashford (1992). Nymphal studies using *A. obscuricornis* revealed that the second instar is the first stage to require plant derived nutrients and is the developmental stadium most prone to high mortality. Future plant utilisation studies using *A. obscuricornis* and *G. tasmanicus* should centre upon this instar as the host selection mechanisms operant at this stage (and presumably the whole of the nymphal stage) are most accentuated, a common situation in herbivorous insects (Scriber and Slansky 1981).

Eclosion in *A. obscuricornis* was found to take between 28 to 80 days depending upon temperature (see Chapter 5), but this work requires additional replication as poor

nymphal survival under controlled conditions limited results. The effect of *Eucalyptus* species upon nymphal growth and development is a topic also warranting additional research as it has very significant implications for host selection in these species.

9.4. Host Plant Utilisation and Adaptive Strategies of *Amorbus obscuricornis* and *Gelonus tasmanicus*.

Eucalyptus is the primary host genus for *A. obscuricornis* and *G. tasmanicus* (Chapters 4, 6 and 7), although species of *Amorbus* having also been recorded from the closely related genus, *Angophora*. Given that eucalypts are perennial and ubiquitous there is no need for these insects to alternate between host genera as do some sucking insects, such as aphids, which feed on annual and/or ephemeral hosts. However, because temperature limits coreid activity and eucalypt growth during late autumn and winter, *A. obscuricornis* and *G. tasmanicus* must diapause during these unfavourable months.

Eucalypts have a distinct bimodal rhythm of shoot growth; periods of greatest shoot extension being referred to as flushes (Specht and Brouwer 1975). Maximum growth occurs in spring and autumn, is reduced during summer and virtually ceases during winter. I have likened the feeding strategy of *A. obscuricornis* to that of "flush" feeding aphids (see Maelzer 1981), because the seasonal phenology of this species is closely timed to coincide with the appearance of eucalypt shoot flushes. Solbreck (1978) termed this phenomenon "resource tracking". The timing of an insect's activity to match the phenology of host plants is not peculiar to aphids, other bugs have also been found to exhibit such behaviour, e.g. *Lygaeus equestris* (L.) (Lygaeidae) (Solbreck and Kugelberg 1972). The term flush feeding also seems highly appropriate to *A. obscuricornis* because of this species' ability to utilise re-sprouting eucalypts. Eucalypts re-sprout or coppice following damage which may result from fire and/or other physical factors. Coppicing eucalypts are both a temporally and spatially ephemeral resource, thus, an ability to locate and utilise such a resource suggests that *A. obscuricornis* is specially adapted to unpredictable resources and habitats.

Wiklund (1974) considered that unpredictable habitats favour selection for an oligophagous habit such as is exhibited by *A. obscuricornis*. That this species is able to be oligophagous on one plant genus is possible given the ubiquity of *Eucalyptus* species. *A. obscuricornis* was found on gum, peppermint and ash *Eucalyptus* species (see Tables 4.3 and 7.2) suggesting that this species either has a wide tolerance of secondary plant compounds or is not influenced by such constitutive defenses. Thus, *A. obscuricornis*

may be oligophagous for eucalypts because selection is less influenced by secondary chemistry than by primary substances, i.e. the water and nitrogen content of shoots (see Chapters 6 and 7).

The presence of nymphs on coppicing trees only (see section 7.3iia), suggests that adult females may selectively oviposit near such hosts. The most obvious cue for this apparent selection is the presence of many soft young shoots. Support for this suggestion is provided by Mitchell (1981), who noted that induction of favourable adult feeding responses may elicit oviposition behaviour in hemimetabolous herbivores. Selection based on such plant characteristics limits the need for apterous nymphs to have to search for additional hosts during their growth, thereby minimising the chances of starvation/desiccation (Chaplin 1980). Use of re-sprouting eucalypts may not only rely upon preferential selection of such resources by adult females, but also on the behaviour of nymphs. For example, greater numbers of second instar *A. obscuricornis* were found on re-sprouting *E. regnans* than normal trees, under artificial conditions (section 7.3iib). Whether nymphs actually chose these hosts on the basis of their shoot quality or simply because they were the first shoots encountered requires resolution. However, whatever the mechanism/s, this behaviour resulted in nymphs locating a nutritionally superior host.

In order to confirm these hypotheses extensive surveys of burnt-out (as per Yen 1989)/damaged and normal eucalypt woodland need to be conducted to ascertain whether *A. obscuricornis* is able to locate and utilise such habitats. Initial surveys suggest that *A. obscuricornis* is able to colonise such habitats, as bug populations on eucalypts damaged by slashing were often higher and temporally more persistent than those in undamaged habitats (see section 7.3i). In addition, it would be extremely useful to ascertain the mechanisms by which such resources are located. Should these hypotheses be confirmed, additional host plant performance assays comparing nymphal development on re-sprouting and normal eucalypt hosts could be conducted to validate the comparative advantage gained by nymphs which are provided with nutritionally superior hosts. Based on the results presented in Chapter 6, I would expect nymphs to attain heavier live weights upon eclosion when reared on the shoots of re-sprouting as opposed to normal eucalypts.

Given that *A. obscuricornis* nymphs develop during summer when eucalypt shoot growth is reduced (Specht and Brouwer 1975) it would be interesting to determine whether scarcity of suitable shoots/*Eucalyptus* species and/or the decline in shoot nutritional quality are important factors influencing the survival of immatures. For example, Velasco

and Walter (1992) found that the availability of different host plants was a significant factor influencing the abundance of *Nezara viridula* (L.) in Queensland. Changes in food plant availability and quality have also been suggested to have a significant effect upon nymphal development in *L. equestris* (Kugelberg 1973).

The host plant utilisation and adaptive strategies of *G. tasmanicus* have not been as well formulated as for *A. obscuricornis*. That *G. tasmanicus* does not appear to feed exclusively upon eucalypt shoots is an important difference between the two species. Based on the avoidance of peppermints by *G. tasmanicus* (see Tables 4.3 and 7.2), it is suggested that secondary plant chemistry may play a more significant role in the host selection mechanisms of this species than for *A. obscuricornis*, however, such suggestions require much additional investigation for confirmation. Alternatively, the significance of abiotic factors such as temperature and rainfall may regulate the distribution of this species and therefore the eucalypts on which it feeds.

All of the studies described in this thesis have utilised eucalypts which were either in juvenile and/or intermediate foliage. It would be interesting to determine whether *A. obscuricornis* and *G. tasmanicus* are host specific for such foliage or whether this was a form of sampling bias. Sampling of mature trees (perhaps using canopy fogging with insecticides as per Majer and Recher 1988; Basset 1990; Kitching *et al.* 1993) would help answer this question. That Hemiptera form a significant component of tree canopy invertebrates is shown in the results of these authors, but unfortunately, only Basset (1990) provided any details concerning the type of Heteroptera collected. This author listed 8 heteropteran families as having been sampled using fogging, of which the most common were species of Miridae. In addition, Basset (1990) collected 127 juvenile Heteroptera of unknown identity. That Bassett collected no Coreidae should not negate the value of similar future studies, as the tree species he sampled was not a eucalypt.

9.5. Effect of Predators, Parasites and Parasitoids on the Distribution and Seasonal Abundance of Tasmanian Coreids.

This study did not concentrate upon the significance of density dependent mortality factors to the distribution and seasonal abundance of *A. obscuricornis* and *G. tasmanicus*. Causal records of such incidences in the field were recorded and the agents involved have been listed in the work detailed in Chapter 8. Relatedly, it needs to be remembered that both species possess pungent defensive secretions (Steinbauer and Davies 1995, back pocket of this thesis) and that nymphs of *A. obscuricornis* are aposematically coloured

(those of *G. tasmanicus* are cryptically coloured). Aposematic colouration in nymphs of *A. obscuricornis* suggests that predation by visually orientated predators such as birds may be of minimal consequence (A. Berryman pers. comm.) and, indeed, no such predation was observed by me. In addition, the proposed resource tracking habit of *A. obscuricornis*, which may cause populations of this species to be patchily distributed and temporally variable in abundance under natural conditions, suggests that control by hymenopterous egg parasitoids such as *Xenoencyrtus hemipterus* (Girault) (Steinbauer and Clarke 1995, back pocket of this thesis) may also be of minor significance (Holt and Hassell 1993, and references therein). Such hypotheses should not be taken to mean that future research in this area is considered of little benefit. On the contrary, such investigation would further our understanding of both species considerably. For example, it is suggested that the importance of ants to the behaviour and survival of nymphal coreids is one area where further investigation could be undertaken (Steinbauer in press, back pocket of this thesis).

9.6. Insect Biogeography and the Degree of Polyphagy: Significance in Relation to *Amorbus*.

The biogeographical and host plant utilisation studies detailed in this thesis, particularly those relating to *A. obscuricornis*, indicate that ecological factors such as host phenology, host availability and nutrient quality are more important to the insect-plant relationships of this coreid, and possibly the genus as a whole, than are plant defensive compounds. These findings are in agreement with the suggestions of Schaefer and Mitchell (1983) concerning differences in selection mechanisms between chewing and sucking insects. By considering the biogeography and host plant utilisation strategy of *A. obscuricornis*, I consider it is possible to infer the potential mechanism by which varying degrees of polyphagy have arisen in the genus.

In most areas of Australia, forest habitats comprise at least two *Eucalyptus* species, typically with at least one from each of two subgenera (Pryor 1959; Duff *et al.* 1983). Thus, eucalypt herbivores such as *A. obscuricornis* are usually confronted with a range of potential host plants. Given that shoot growth differs between *Eucalyptus* species (Specht and Brouwer 1975), this insect may be limited if reliant upon one *Eucalyptus* species providing sufficient resource to meet it's requirements. Thus, there is a selective pressure to use more than one species as a host.

Additionally, the range of available *Eucalyptus* species changes with geographic region.

Thus, species of *Amorbus* with wide geographic distributions are not only confronted with an array of host species of different seasonal phenologies and nutritional qualities within a region, but also between regions. Moreover, the different host plant requirements of adults and nymphs further confound the dilemma faced by such insects, i.e. adults need to locate hosts where they will find a mate, can feed and which is suitable for oviposition; while nymphs need a host, or area of suitable hosts, which will provide sufficient quantity and/or quality of shoots to ensure eclosion. That the host plant requirements of heteropteran adults and nymphs may vary has been demonstrated by Velasco and Walter (1992), who showed that hosts which maximised the longevity of adult *Nezara viridula* L., did not necessarily support nymphal growth. Under such circumstances Wiklund (1974) proposed that insects may exhibit some degree of oligophagy where two basic strategies are employed. Firstly, in the "monophagous strategy" the insect uses only one host plant species in any one population, but exploits many species over it's whole geographic range. In the second "polyphagous strategy", the insect population uses all available host plants belonging to a narrow range of species, showing no preference for any one. The mechanisms by which oligophagy may evolve have also been considered by Courtney (1982) and Singer (1983).

Given that *A. obscuricornis* can be found on a number of *Eucalyptus* species within a site, I consider that this species utilises a variation of Wiklund's "polyphagic strategy" with selection between hosts being based on which species has the superior nutritional quality. Thus, hosts which are constantly architecturally and/or nutritionally superior may be preferentially chosen on a regular basis regardless of their botanical identity. However, such "preferences" are not static, but rather dependent upon the phenologies of available hosts and therefore the dynamic environmental factors which have the capacity to modify hosts, e.g. temperature, rainfall and fire. Wiklund (1974) considered that the polyphagic strategy was generally adopted in unpredictable habitats. I consider that although the sclerophyll forest habitat is generally not unpredictable, there is variation in the quantity and quality of eucalypt shoots. This is particularly true of coppicing hosts whose availability is very temporary and unpredictable.

Agreement with Wiklund's polyphagic strategy hypothesis would explain why species such as *A. rubiginosus*, which is distributed over almost the entire continent (see Appendix 3), has been collected from many *Eucalyptus* and *Angophora* species (see Table 4.3). Similarly, the array of hosts from which *A. obscuricornis* has been collected can be explained by it's distribution throughout much of south-eastern Australia. In the case of

A. obscuricornis, oligophagy is not only a reflection of it's distribution but also to the fact that the south-eastern region of Australia represents an area of high *Eucalyptus* species diversity (Chippendale 1988). In contrast, species such as *A. bispinus* may have adopted the monophagic strategy because they are confined to a region in south-west Western Australia where the most abundant host encountered is *E. marginata*, which typically occurs in monospecific stands.

9.7. Potential Economic Significance of Tasmanian Coreids to Plantation Forestry and Concluding Comments.

Based on studies of host plant injury, I consider that of *A. obscuricornis* and *G. tasmanicus*, it is only the former that presents a potential threat to plantation eucalypts, even though the latter has been found in large numbers in some coupes (pers. obs). The basis for this statement is that the shoot wilting habit of *A. obscuricornis* is not commonly shared with *G. tasmanicus* (pers. obs). Moreover, given the current tendency in temperate Australia to establish plantations of *E. nitens* and *E. globulus* (Symphyomyrtus), it would seem that the potential significance of *A. obscuricornis* has been somewhat negated, given the higher rate of nymphal establishment on eucalypts with more readily accessible shoots, e.g. juvenile ash and many peppermint species. Despite this situation, it is still worth commenting on means by which populations of *A. obscuricornis* could be kept at low levels without the need for damaging pesticides.

The biological and ecological findings detailed in this thesis would suggest that the best form of management for *A. obscuricornis* is one of risk avoidance/minimisation. For ash plantations, plantings should be avoided near areas where there are reasonable numbers of re-sprouting eucalypts, e.g. burnt-out eucalypt forest or areas where trees are regularly slashed such as near roadsides or beneath powerlines. Such eucalypts are likely to attract adult *A. obscuricornis* which may then migrate to nearby undamaged plantation trees. Ideally, plantations should always be planted on fertile sites, thereby, minimising possible chronic *Amorbus* infestations by maximising eucalypt growth rate. If trees are slow growing they may develop a dense canopy which can harbour *A. obscuricornis* and lead to resident populations becoming established. Although it should be expected that most young ash plantations will suffer some level of infestation by *A. obscuricornis*, if these trees are growing on superior sites it is likely that they will more quickly attain a size and architecture which limits coreid damage.

In both ash and *E. nitens* plantations it would be worthwhile to monitor for the

appearance of damaged trees which may be the result of management practices, vertebrate activity and/or storm damage. Such trees could act as foci for *Amorbus* infestations. In such instances it would be wise to either totally destroy the tree in question or monitor the regrowth to ensure that adult *A. obscuricornis* do not infest the resource. The deliberate planting of other eucalypt or native plant species, together with the limitation of plantation size (Abbott 1993) could also reduce the risk of significant population outbreaks of *A. obscuricornis*.

Minimisation of damaging *A. obscuricornis* populations using pheromonal attraction of control agents (as per Aldrich 1991) and/or the mass release/augmentation of egg parasitoids such as *X. hemipterus* would appear to be possible management options requiring further study. Based on current levels of coreid damage, such studies are not, however, ever likely to be of economic value.

As with any research on a novel topic, the investigator is often forced to abandon a particular area of study with just as many, if not more questions awaiting resolution as when they commenced. Such is my predicament, but it is hoped, however, that the work detailed in this thesis has opened the way for later investigators who may be given the opportunity to study eucalypt feeding coreids.

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Appendix 1

Explanation. Presented below in small font are translations of original species' descriptions. Terms in { } represent alternative translations to the original text, whilst those in [ ] are actual portions of the original text supplied to facilitate interpretation of the English translation given. Words and phrases enclosed in « » are provided to assist with interpretation of the translations given (e.g. often these words were implicit in the context of the original Latin description (P. Davis pers. comm.)). Not all published references which cite a given species are listed only those which are of a taxonomic basis and/or have some other significance (e.g. mention suspected species synonymy and alike).

A number of the original descriptions provided herein use a unit of measurement with the abbreviation "lin." This abbreviation was found to stand for a unit of length called a "line" (S. Shattuck pers. comm., ANIC, Canberra). According to S. Shattuck a line is equivalent to the following lengths in millimetres:
1 French line ≡ 2.25 mm,
1 English line ≡ 2.12 mm,
1 German line ≡ 2.19 mm.
The conversion factor which corresponds to the language in which the description was written and/or the country of origin of the author have been employed where-ever required. Yet other descriptions use the abbreviations "mill.", "milli." and/or "m" which presumably all stand for millimetres.

Prior to it's official proclamation on the 17th December 1855, "Van Diemens Land" (abbreviation V.D.L) had been the given name for the state of Tasmania. Similarly, the name "Australia" received vice regal approval during April 1817 following it's usage by Govenor MacQuarie, however, the name was never formally declared. "Australia" had been in common use from the earliest days of settlement. Prior to this time Australia was known as "New Holland" (abbreviation N.H.). Both of these names appear in the translations presented below.

Gelonus Stål

"...28 (29). Medial lobe of the head between antenna-bearing tubercles not to be distinguished, not prominent. - *Amorbus* DALL.
29 (28). Medial lobe of the head between antenna-bearing tubercles to be distinguished, somewhat prominent, however not raised between those tubercles. - *Gelonus* STÅL...." **(Stål 1865)**

"...4(5), The apical joint of the antennae and the third joint or its apex are equally thick; the last dorsal segment of males known to me is obtusely rotundate at the apex; the rear femora of the males are very thickened; the rear tibiae of the males are more or less dilatate below, denticulate behind the middle; the tylus when seen from above is not to be distinguished or is much less prominent than the antenna-bearing tubercles. - *Amorbus* DALL.
5(4). Apical joint of the antennae is thicker than the third joint, the last dorsal segment of males is drawn forward at the apex into a broad transverse process; the rear tibiae of the males are unarmed; the rear femora of the males are gradually very lightly thickened; the front femora are not thicker; the tylus when seen from above and the antenna-bearing tubercles are equally prominent in length. - *Gelonus* STÅL...." **(Stål 1873)**

Gelonus tasmanicus (Le Guillou)

"16. *Syromastes Tasmanicus.* Deplanate, brown, prothorax with dentate sides; abdomen dilatate [*abdomine dilatato*], rotundate; brown antennae, second joint and fourth base testaceous; brown feet, paler at base {than base}. - (Length 13, width 6 m. Habitat Hobart-Town.)" **(Le Guillou 1841)**

"9. AMORBUS discolor, n.s.
A. above indistinctly fuscous, punctate, fulvous below; antennae of uniform colour, at the third joint, paler, not quite ferruginous, at the apical base whitish: margins of the abdomen blackish, fulvo-fasciate. ♀. Length in lines 6½ «≡ 13.8 mm». «Latin portion»
Above dark brown, obscure, thickly and rather finely punctured, and clothed with minute yellow hairs. Head

blackish, with the antenniferous tubercles brown, and with a reddish brown longitudinal streak on the vertex. Thorax rugose, with the lateral margins irregularly denticulate, the lateral angles somewhat prominent, obtuse. Coriaceous portion of the elytra with a whitish point on the disc a little behind the middle; membrane blackish. Margins of the abdomen projecting considerably on each side, blackish, with a narrow fulvous band at the base of each segment. Body beneath fulvous; abdomen thickly and minutely punctured, with the stigmata and some irregularly placed points near them, and two rows of spots on the disc, black. Breast thickly punctured, with some of the punctures black on each side of the mesosternum; prosternum with a black central spot. Thighs testaceous at the base, brownish at the apex, where there is a single acute tooth beneath; tibiae testaceous, with the base and apex brown; tarsi testaceous, with the apex brown. Head beneath fulvous, with a black central spot. Rostrum pale fulvous, with the apex black. Antennae with the basal joint brown; second joint reddish, with the apex dark brown; third joint ferruginous, with the base and apex pale; fourth joint dark brown, with the base whitish.
a. Van Diemen's Land. Presented by the Rev. T. Ewing. «English description»" **(Dallas 1852)**

"...§ Middle lobe of the head not prominent nor distinguishable between the antenniferous tubercles. - - - - - 14. AMORBUS.
§§ Middle lobe of the head slightly prominent, distinguishable, but not elevated between the antenniferous tubercles. - - - 15. GELONUS....
Genus 15. GELONUS.
Gelonus, *Stal, Hem. Afr.* ii. 3.
1. GELONUS DISCOLOR.
Amorbus discolor, *C.H.* 411—Gelonus discolor, *Stal.*
a. Tasmania. Presented by the Rev. T. Ewing." **(Walker 1871)**

"GELONUS STÅL.
STÅL, H. afr. 2. p. 3. (1865).
1. **G. tasmanicus** LE GUIL. - *Syromastes Tasmanicus* LE GUIL., Rev. zool. 1841. p. 263. 16. - *Amorbus discolor* DALL., List. 2. p. 411. 9. (1852).
Country: Adeliade. (Mus. Holm.); Tasmania." **(Stål 1873)**

Acantholybas Breddin

"Acantholybas n. gen.
Head tiny, triangular, including the eyes a little wider than long, above behind antennal tubercles on exterior margin armed with horizontal spinula. Eyes tiny, but distinct. Bucculae raised towards the front into open angle, at the highest angle armed with almost obsolete apiculus. Antennae moderate in size; first joint quite short, shorter than head; second joint longest of all; third and fourth joints almost equal, individual «joints» distinctly longer than the first joint. Pronotum trapezoidal; shoulders rounded, not prominent; anterolateral margins almost straight, and they are prominent behind narrowing of the neck antrorse into very distinct almost subconical tubercles [*pone stricturam collarem antrorsum in tuberculos distinctissimos subconicos prominentibus*]. Scutellum flat. Hemelytra and complete wings; membrane quite thickly venose. Hook of wing rising a little before base of down-running vein. Larger basal part of venter distinctly furrowed lengthwise. With little glandular, intraspiracular warts on the fourth, fifth and sixth ventral segments surrounded by ring-shaped depression. Feet barely middle-sized, femora unarmed, tibiae above flattish. Rostrum slender, very clearly surpassing base of venter; third and fourth joints of almost equal length. Genital segment of male unarmed above; sixth ventral segment in female[1]) whole.
Very easily distinguished from neighbouring genera by antennal tubercles armed at base with spine, hook of wings removed from base of down-running vein and sixth ventral segment whole in female...
[1]) I have only been able to examine the female of *A. brunneus* from Australia." **(Breddin 1899)**

"*h*. The sixth «*Acantholybas* is the sixth genus described in the key, however, for this sentence to agree with this supposed context "*sextus*" would need to be replaced with *sextum*. P. Davis, pers. comm.» with antennal tubercles armed with a very sharp spinule. Tibiae not sulcate. *Acantholybas* Bred.
hh. Antennal tubercles unarmed without. Tibiae (at least in specimens known to me) distinctly sulcate. *Sciophyrus* Stål." **(Breddin 1900b)**

Acantholybas longulus Breddin

"A. longulus n. spec.
(Fig. 5.)
Body prolonged, nearly parallel from the shoulders continually lengthwise. Head rather small, together with its eyes a little shorter than its own width. The space positioned between the eyes and antennal tubercles a little bit shorter than the longitudinal diameter of the eye; the exterior spines of the antennal tubercles are horizontal, acuminate The extremity of the tylus above the insertion of the rostrum is drawn out to a subreflex apex. The trapezoidal pronotum, being shorter than its own humeral width, is moderately declivous towards the front; the declivous part barely convex, behind the cicatrical region crosswise somewhat depressed, and the antero-lateral

margins in the same place are as lightly as possible sinuate. The marginal subapical tubercles of the pronotum are briefly conical, obtusate at the apex. The scutellum towards the apex is almost indistinctly carinate lengthwise. Most of the puncta of the clavus are arranged into three series (of which one follows the scutellar margin, two the suture of the clavus). The veins of the membrane are quite dense and quite often furcate. The abdomen, at least in the male, is rather narrow, barely surpassing the closed hemelytra sideways. The second joint of the antennae is almost double the first and the third is longer by almost one third part. The rostrum touching or surpassing the middle of the third ventral segment; the first does not extend beyond the base of the head; the second is a little longer than the third. The tibiae are longer than the femora; the tarsi are rather small; the basal joint is barely longer than the two apical «joints» taken together. The whole body is densely punctate, the puncta are armed with individual very short yellowish setulae, the upper head and cicatrical area of the pronotum gradually thicker and equally puberule [*puberulis*]; the venter on this side and that side and the lower surface [*facie*] of the femora except for those setulae are erect with some long hairs, the tibiae below are equipped with semicubant hairs below.

The body above is darkly blackish-brown, below dull rusty-tawny, fusco-punctate. Antennae, rostrum and feet blackish or pitch-coloured; almost all the first joint of the antennae and of the second joint a little more dilute than the base itself. The lowest base of the third joint, almost the third apical part of the fourth joint, the apex of the scutellum, the rear margin of the connective segments, the little callus placed at the apex of the ostioles, the basal part of the first joint of the rostrum, the lowest part of the apex of the second joint, the base of the second joint of the tarsi, the ring placed behind the middle of all the tibiae, the trochanters of the rear feet at the base and the two femoral rings (one basal, one post-median) more or less dully yellowish. The anterior femora, in my own specimen, barely exhibit very indistinct shadows on the two rings, in more dilute individuals probably more distinctly annulate. Membrane black-fuscous; basal line marking the suture of the membrane, the bases of the veins in inner angle of membrane of those being born and the transversal sub-basal vein are tawny-yellow. Wings transparent, lightly tawny-coloured; veins dilutely greyish. Dorsum of the abdomen rusty-brown or dully goldish-red.

Genital segment of the male is convex, towards the apex gradually narrowed, the upper margin quite narrowly corrotundate.

Length of body 10.5 mm, width of shoulder 3.2 mm.

[*Sapit*], April (collection of the author)." **(Breddin 1899)**

"**Acantholybas** (2) **longulus** Breddin.

Genae unarmed. Ring of the rear femora and shadow of rings in forward femora in other specimens, which I have examined, missing. Dorsum of the abdomen often cermesine-black.

♀. Abdomen distinctly broader than the shoulders, hemelytra cut short (deprived of limbs) not completely reaching the sixth true dorsal segment. Seventh true ventral segment (as I had already suspected *Hem. ins. Lombok*, p. 16) whole, the middle backwards lightly rotundate-producted and there distinctly longer than towards the sides. The body in the only female specimen, which I have seen, somewhat more dilute than in the males known to me (above dully ochre-brown). The femora (excepting the lutescent bases) and the tibiae dully ferrugineous, not ringed; these infuscate towards the apex with the tarsi...

(2) *Acanthocolpura* m. (*Entom. Nachr.*, 1900, XXVI, p. 40) = *Acantholybas* m. (*Hem. ins. Lombok*, p. 15)." **(Breddin 1900b)**

Acantholybas brunneus (Breddin)

"*Acanthocolpura brunnea* n. spec.

Body almost elongated, abdomen very broad around apex of fourth segment, but not surpassing the shoulders by much. Antehumeral part of the pronotum together with the head antrorse only lightly sloping downward. Lateral spines of the head somewhat weak, very acute. Pronotum broader than its own length around about the fifth part, trapezoidal, above a little before the centre crosswise lightly depressed and there on the antero-lateral margins lightly sinuate; these margins behind the narrowing of the neck coming into tiny, almost obtuse tubercle. Rear margin truncated above base of scutellum. Middle of scutellum not or barely longer than its own basal width. All the veins of the corium are raised and very distinct, both first and second sectors forked before the apex, with two inner branches soon to come together into one. First segment of venter at rear margin of metasternum almost completely covered, only to be distinguished around the middle but here too very short. The fourth and fifth ventral segments transverse-wise somewhat depressed around the middle. Rostrum almost surpassing the middle of the third ventral segment; first joint not or barely longer than the head; second and third joints are of equal length; fourth joint somewhat longer than this. Basal joint of the rear tarsi almost of equal length with two apical «joints» taken together. Second joint of the antennae distinctly longer than the third (almost = 3:2); fourth joint subclavate, the third a little longer.

Dull rusty-brown, below including the feet the base of the antennae is rusty-tawny, dark and clothed in appressed almost-tawny setulae, fusco-granulate in the upper part of the head, pronotum, scutellum, the rest fusco-punctate, these points flowing together on the venter into spread out pitch-coloured little stains. On the postocellar part of the head, the second, third joints of the antennae towards the apex, excepting the base, the basal half of the fourth, the three apical joints of the rostrum, on the femora many rounded stains placed in series, on the forward femora at base and apex, the rear femora at the apex more or less flowing together to a

fuscous colour, and glandular impressions of the venter within are fuscous or black. Two rings of the tibiae, one antemedian, the other occupying the apex, are somewhat fuscous, often obsolete. At the apex of the scutellum, at the rear margin of the connective segments, the margins of the ostiolae «Breddin uses the masculine/neuter form of the word whereas it is actually feminine» callose, at the base of the third joint of the antennae, at the apical half of the fourth, and the first joint of the rostrum are ivory or somewhat tawny. The head rust-coloured, showing three rather dilute longitudinal lines, one at the middle, others following the inner margin of the eyes. Membrane grey, the veins dull whitish. Wings tawny-vitreous. The dorsum of the abdomen somewhat fuscous-crimson, punctate, the cicatrices between the third and fourth segments and the fourth and fifth segments are whitish.

♂: Genital segment broadly oval; the upper margin corrotundate.

♀: Sixth ventral segment slightly extended backwards at middle and rotundate and there the fifth segment is distinctly longer than the middle.

Length of body 9-9¼ mm; width of shoulder 3 mm.

N. South Wales (my collection).

Similar in colour and size to *Pachycolpura manca*; rostrum much longer, structure of the sixth ventral segment in the female is easily distinguished by the hemelytra and complete wings." **(Breddin 1900a)**

Acantholybas kirkaldyi Bergroth

"**Acantholybas Kirkaldyi** n. sp.

Oblong-ovate, fuscous-testaceous, sufficiently densely fusco-punctate, the head blackish above, with juga on top at sides [*jugis apice lateribus*], with occipital vitta [*vitta occipitali*], with rounded spot above on either side behind the eye, with bucculae, first joint of rostrum, at frontal half of lateral margin of pronotum with tubercle of its apical angles, at apex of scutellum, with apical fascia of segments of connexivum and at margin of acetabula palely testaceous, membranes black-fuscous, veins barely paler, denudate black spot at lateral anterior angle of mesopleuron {mesopleura [*mesopleurae*]} and something within spiracula {spiraculae [*spiracula*]}, venter blackish-variegate, antennae and feet fusco-black, at the base of their third joint blood-red, at the fourth joint excepting the base palely ferrugineous, at top of coxae, at base of femora, a lower anteapical spot of anterior femora, anteapical ring of hind femora and with broad submedian ring of all tibiae fulvo-luteous. Head equally long and broad, tylus quite broad at top, obtuse, ocelli equally far distant from eyes and a line in middle of the head, a lateral spine verging a little outside antenniferous tubercle, at space between eyes and base of antennae eyes a little longer than longitudinal diameter [*spatio inter oculos et basin antennarum diametro longitudinali oculi paullo longiore*], the first joint of antenna overtopping the top of the head by a part more than a half, the second twice as long as the first, the third longer than the first by a half, the fourth distinctly longer than the third, rostrum (mutilated) plausibly touching middle of stomach underneath, the first joint overtopping the frontal edge of prosternum somewhat, second touching the middle coxae, third a little shorter than the second, touching underneath the middle of the second segment of stomach (fourth joint missing). Pronotum at the middle of its length broader by half, before the middle towards the front fitted with a curved transverse impression towards the sides [*ante medium impressione transversa latera versus antrorsum curvata præditum*], lateral margins erect, before middle not unless indistinctly sinuate [*ante medium non nisi obsolete sinuatis*], tubercle of apical angles briefly conical. Hemelytra almost touching apex of abdomen, subcostal vein of corium clearly raised Abdomen below from middle of its base sulcate right up to top of fourth segment, first segment distinct through whole width, not covered by metasternum, genital segment of male oval, upper margin light sinuate at middle (almost as in *Colpura hebeticolli* BREDD. (1). - Length of ♂ 10 mill.

Tasmania.

Akin to *A. brunneo* BREDD., but differently coloured and rostrum much longer, easily distinguished by pronotum much shorter, stomach distinctly sulcate, first segment of this not covered at sides, and genital segment of male sinuate above at top...

(1) Cfr. *Ann. Soc. Ent. Belg.*, 1906, 52." **(Bergroth 1909)**

Amorbus Dallas

"...1. Third joint of the antennae more or less compressed.

α. Thorax unarmed.....1. BRACHYTES.

β. Thorax with the lateral angles produced into flat lobes.. .3. DALADER.

2. Third joint of the antennae cylindrical.....14. AMORBUS....

Genus 14. AMORBUS, n. g.

Head emarginate between the antenniferous tubercles. Antennae rather more than half the length of the body, of four joints; first three joints variable in proportion, third cylindrical; fourth joint shorter than the third. Rostrum short, not passing the anterior coxae, of four nearly equal joints; basal joint not reaching the base of the head; fourth joint slender. Body oblong or ovate. Thorax rhomboidal. Abdomen more or less ovate, especially in the females, in some of which the margins are very prominent, nearly foliaceous; margins not spinous. Breast with a very small, short canal, or rather an emarginated tubercle, at the anterior margin of the mesosternum between the anterior coxae. Posterior thighs thickened in both sexes, much thickened in the males; posterior tibiae in the males, and sometimes in the females, furnished with a tooth on the inner margin." **(Dallas 1852)**

"...28 (29). Medial lobe of the head between antenna-bearing tubercles not to be distinguished, not prominent. - *Amorbus* DALL.
29 (28). Medial lobe of the head between antenna-bearing tubercles to be distinguished, somewhat prominent, however not raised between those tubercles. - *Gelonus* STÅL...." **(Stål 1865)**

"AMORBUS DALL. List Hem. II, p. 408 (1852).
The species of this genus can easily be divided into two groups, in the first group the upper side of the body is densely covered with small grains, while the other group is spotted. In the first group each grain has a very small posterior hair attached, while the second group, has such fine hairs attached in the subsiding spots." **(Mayr 1868)**

"...§ Middle lobe of the head not prominent nor distinguishable between the antenniferous tubercles. - - - - - 14. AMORBUS.
§§ Middle lobe of the head slightly prominent, distinguishable, but not elevated between the antenniferous tubercles. - - - 15. GELONUS....
Genus 14. AMORBUS, *C.H.* 408.
A. Prothorax granulated.
a. Corium not bordered with yellow.
* Abdomen elongated.
† Antennae dark. - - - - - alternatus.
†† Antennae pale. - - - - - hirticulus.
** Abdomen hardly elongated.
† Abdomen not projecting beyond the costa. - angustus.
†† Abdomen projecting rather beyond the costa.
‡ Antennae pale.
§ Prothorax broad. - - - - rubiginosus.
§§ Prothorax narrow. - - - - rhombeus
‡‡ Antennae dark.
§ Pectus pale.
x Legs dark. - - - - - obscuricornis.
xx Legs pale. - - - - - planus.
§§ Pectus black. - - - - - abdominalis.
*** Abdomen projecting much beyond the costa. - rhombifer
b. Corium bordered with yellow. - - - robustus.
B. Prothorax punctured. - - - - rubicundus." **(Walker 1871)**

"...4(5), The apical joint of the antennae and the third joint or its apex are equally thick; the last dorsal segment of males known to me is obtusely rotundate at the apex; the rear femora of the males are very thickened; the rear tibiae of the males are more or less dilatate below, denticulate behind the middle; the tylus when seen from above is not to be distinguished or is much less prominent than the antenna-bearing tubercles. - *Amorbus* DALL.
5(4). Apical joint of the antennae is thicker than the third joint, the last dorsal segment of males is drawn forward at the apex into a broad transverse process; the rear tibiae of the males are unarmed; the rear femora of the males are gradually very lightly thickened; the front femora are not thicker; the tylus when seen from above and the antenna-bearing tubercles are equally prominent in length. - *Gelonus* STÅL....
AMORBUS DALL.
DALL., List. 2. p. 377 and 408 (1852); STÅL, H. afr. 2. (1865).
a. *With long bucculae; shorter rostrum, at the first joint not extended behind bucculae; rear coxae almost equally distant between themselves and from the sides of the body; with juga below antenna-bearing tubercle before the tylus not projecting slightly; head ferruginous above or ferrugineo-flavescent, equipped with two black vittae; abdomen less wide; genital dorsal segments of equal length.*" **(Stål 1873)**

Amorbus abdominalis Dallas

"6. AMORBUS abdominalis, n. s Pl. XII. fig. 8.
A. above, with chest, feet, antennae blackish; scutellum apex punctum whitish; abdomen very dilatate, almost circular, red. ♂.
Length in lines 9½ «≡ 20.1 mm». «Latin portion»
Oblong ovate; above blackish brown, somewhat opaque. Head covered with very minute, whitish elevated points. Thorax thickly and rather strongly punctured, and covered with minute whitish points; lateral margins slightly curved outwards towards the lateral angles, which are somewhat prominent. Scutellum rather long, rather strongly punctured, and covered with white points like those on the head and thorax; the apex slightly elevated, yellowish white. Coriaceous portion of the elytra thickly punctured, and covered with minute, white, elevated points, and with numerous scattered, irregular brown patches, membrane pitchy. Margins of the abdomen very prominent, pitchy black, covered with very minute, elevated, whitish points, with a small yellow

spot on the edge of each segment close to the base, and the posterior margin of each segment, reddish. Abdomen beneath red, covered with minute, pale, elevated points. Breast pitchy, thickly and rather strongly punctured, and covered with numerous, very minute pale, elevated points. Legs blackish, covered with minute pale brown or whitish points; posterior thighs much thickened, with a tolerably distinct ridge along the upper surface, and a strong tooth near the apex beneath; posterior tibiae compressed and widened from the base to beyond the middle; the wide portion terminated on the inner margin by a somewhat acute tooth; the apical portion curved outwards, with four or five denticulations on its inner margin. Rostrum pitchy, becoming reddish towards the apex, with the tip black. Antennae black; first three joints and the base of the fourth covered with minute, elevated, whitish points, the remainder of the fourth joint hairy; second and third joints about equal, longer than the first.
a. Kangaroo Island. Presented by the Entomological Club. «English portion»" **(Dallas 1852)**

"6. AMORBUS ABDOMINALIS, *C.H.* 410.
a. Kangaroo Island. Presented by the Entomological Club." **(Walker 1871)**

"8. **A. abdominalis** DALL. - *Amorbus abdominalis* DALL., List. 2. p. 410. 6. pl. 12. f. 8. (1852).
Country: Adelaide (Mus. Holm.); Kangaroo Island." **(Stål 1873)**

Amorbus damelus Distant

"*Amorbus damelus*, sp. n.
♂. Head, antennae, pronotum, and corium cinnamomeous; body beneath and legs testaceous; abdomen above black, with two prominent, central, transverse, discal red spots, one each at the anterior margins of the fourth and fifth segments and a very narrow spot at the anterior margin of the sixth segment; connexivum testaceous, with marginal elongate black spots; antennae moderately robust, joints 1-3 almost subequal in length, remaining joint mutilated in typical specimen; head with a submarginal black fascia on each side; pronotum thickly finely granulose, the lateral margins slightly recurved and more or less shaded with black; scutellum black; corium thickly punctate; membrane bronzy brown; body beneath more or less finely granulose; posterior femora distinctly thickened, somewhat sinuate, inner margin shortly serrate, shortly but more prominently toothed a little before apex; posterior tibiae very strongly curved, inwardly toothed, the tooth a little nearer base than apex, from tooth to apex the inner margin is shortly serrate.
Length, ♂ 19 mm.
Habitat New South Wales (*Edward Damel*, Brit. Mus.).
Allied to *A. alternatus*, Dall., by the apparently shorter and distinctly much more curved posterior tibiae, different colour of the abdomen above, &c.
Some difficulty occurs with the species described as *A. planus*, Walk., and which, as I pointed out in 1900 (Ann. & Mag. Nat. Hist. (7) vi. p. 376), is a synonym of *A. alternatus*, Dall. This applies to the female, which he first described; he then added a description of a male specimen, which is another species altogether, and forms the type of the above." **(Distant 1911)**

"*Amorbus damelus* Distant 1911
Amorbus damelus Distant is almost certainly a synonym of *alternatus* Walker but for the record it shows the following points of difference with an *alternatus* male.
1) It is rather smaller
2) The hind femora look proportionately a bit more slender
3) The scutellum appears to be black but this may be discoloration around the verdigris pin.
4) The dorsum of the abdomen is a wine red or purplish red with some semicircular reddish spots in the middle of the base of the 5th or 6th segments. *Alternatus* has a largely yellow dorsum to the abdomen with brown bars across some of the incisures, varying a lot." **(Gross 1969 *in lit.*)**

Amorbus affinis (Westwood)

"Above dark fuscous, the 2nd (except the base) and 3rd joints and the base of the 4th of the antennae being fulvous, the pronotum granulose, the most slender lateral margin fulvous, the corium of the hemelytra dark fulvous, black very punctate [*nigro punctatissimo*], the apical membrane blackish; the abdomen broadley ovate, the back and base orange-coloured beyond half, black at the back, the revealed sides fuscous, a very small, whitish point at the base of single segment, the body wholly whitish-yellow below, the femora below the tibia and the tarsi fulvous-red, the rear femora not very thickened upright tibia.
Length of body in lines 9 «≡ 19.1 mm». ♀ Lives in New Holland." **(Westwood 1842)**

"SPECIES TREATED AS SYNONYMIC...
Physomerus affinis Westw. l. c. p. 9 = *Amorbus rubiginosus* Guér." **(Distant 1901)**

"Physomerus affinis Westw. New Holland
Male 18.26 mm long, pronotal humeral width 6.8 mm, maximum width across abdomen/connexivum 7.9 mm. Females (two) one labelled type by Distant. 18.26-18.42 mm long, pronotal humeral width 6.9-7.4 mm,

maximum width across abdomen/connexivum 8.9 mm.
Females clearly more rhomboid than male.
Figs. 14-19 Male. Fig. 18 'scent gland' rim not greatly enlarged.
Abdomen with two (1+1) rows of black 'V' shaped marks (fig. 16).
Figs. 20-22 females, 'scent gland' rim (fig. 22) not differing greatly from male.
Antennae of male 35-37-34 = 2.9-3.0-2.82 mm...
Antennae of female (type) 30-32-33-18* *tip broken off = 2.49-2.65-2.73-1.49 mm.
Antennae of female (not type) 33-38-38-35.5 = 2.73-3.15-3.15-2.94...
Affinis- ♀ 'type' according to WLD «W.L. Distant», hind femora with several rows of larger maculae amongst smaller speckling. Second ♀ (not seen by WLD)?? similar to 'type'.
Still on original pin, very robust hind femora with prominent larger maculae. The ridge along 'anterior' margin with very prominent maculae...
Affinis-N.H. Lectotype? ♀, red circular type label; Distant labelled ♀ Amorbus rubiginosus Guer. 'Holland' printed label. Paralectotype ♀? N.H. identical to lectotype- possibly not seen by Distant as it does not have any of the labels he placed on what he considered to be Types.
Paralectotype ♂? very much like lectotype, no label other than N.H. Male differs from ♀♀ as it is still on its original pin whereas ♀♀ have been repinned.
In the original Hope/Westwood Coll. there are 2 ♂♂, one labelled N.H. with a label in Westwood's hand Ph. rubiginosus? Va (s); second male has a label in Westwood's hand Coreus rubiginosus Guer. Ic. pl. 55 6. The two male "rubiginosus" have the 'dorsal surface' of the hind femora broadly black and numerous maculae whereas the male hind femora of affinis is dorsally streaked black with fewer maculae." **(Lansbury 1992 *in lit.*)**

Amorbus alternatus Dallas

"1. AMORBUS alternatus, n. s.
A. almost elongate pale brownish above, fusco-punctate, and speckled with minute whitish points; testaceous below; different margins of the abdomen are yellow and black, albo-punctate. ♀.
Length in lines 10½ «≡ 22.2 mm». «Latin portion»
Elongate ovate; above pale brownish, thickly punctured with brown, and with a minute elevated whitish point close to each brown puncture. Head with an irregular blackish streak on each side within the lateral margins. Thorax rather darker and more thickly punctured than the rest of the body, with the lateral margins straight, very finely crenulated, and with a blackish line close to each lateral margin. Scutellum with the apex testaceous Coriaceous portion of the elytra with the outer margins blackish, the extreme edge of the basal portion finely crenulated with minute whitish tubercles. Membrane brown, slightly brassy, with the nervures darker. Margins of the abdomen banded with yellow and black or brown (the dark band being hindmost), and irrorated with minute whitish elevated points. Body beneath testaceous; breast punctured and furnished with minute whitish elevations, but less thickly than the upper surface; abdomen impunctate, but with the disc rather thickly, the sides more sparingly, covered with minute elevated points Legs brownish testaceous, covered with minute elevated whitish points; anterior and intermediate thighs brownish towards the apex, tibiae brownish towards the base; posterior thighs considerably thickened, with the upper surface brown, irrorated with whitish points and with two indistinct rows of larger dots; furnished beneath with two rows of small teeth; posterior tibiae compressed, slightly curved inwards at the middle, outwards at the apex; the inner margin with an acute tooth at the middle, and the apical half finely denticulated; tarsi pale testaceous, with the claws tipped with black. Rostrum short, not reaching the anterior coxae, pale testaceous, with the tip of the last joint black. Antennae pale brown, becoming paler towards the apex; second joint longer than the third; first three joints and the base of the fourth covered with whitish elevated points like those of the body; apical portion of the last joint clothed with hairs.
a. Australia. «English portion»" **(Dallas 1852)**

"1. AMORBUS ALTERNATUS, *C.H.* 408.
a. Australia." **(Walker 1871)**

"1. **A. alternatus** DALL. - *Amorbus alternatus* DALL., List. 2. p. 408. 1. (1852).
Country: northern Australia; Moreton Bay; Port Denison. (Mus. Holm.)
Dorsal segments of abdomen towards the back nigro-maculate or nigro-fasciate. Final dorsal segment of male at apex obtusely rotundate and subsinuate on both sides. Rear tibiae of either sex before middle angulate below, among females much narrower than among males." **(Stål 1873)**

"AMORBINAE.
Genus AMORBUS.
Amorbus alternatus.
Amorbus alternatus, Dall. List Hem. i. p. 408. n. 1 (1852).
Amorbus planus, Walk. Cat. Het. iv. p. 42. n. 11 (1871)." **(Distant 1900)**

"**Amorbus alternatus** Dall. I. New Holland, Deyrolle." **(Blöte 1938)**

Amorbus angustior (Westwood)

"Akin to the previous one «namely *Physomerus affinis*» and much narrower. Brownish-reddish, granulose, joints 2, 3 and base of 4th of the antennae red, the apical membrane of the hemelytra blackish, parallel sides of the abdomen scarcely extended behind hemelytra; beneath the body red feet, rear femora not thickened beneath in middle of conical tooth with armed tibiae curved pressed inwards in the middle angulate. ♂
Length of body in lines 8¼ «≡ 17.5 mm». Lives in New Holland." **(Westwood 1842)**

"4. AMORBUS angustior.
Physomerus angustior, *Hope, Cat.* 9 (1842).
a. N. Holland. Presented by Sir John Richardson, M.D." **(Dallas 1852)**

"*a)* Granulate species...
A. ANGUSTIOR Westw.
Physomerus angustior Westw. Hope Cat. II, p. 9 (1842).
Amorbus angustior Dall. List Hem. II, p. 410 (1852).
Sydney in New Holland.
This species has a red abdomen without black spots and red antennae, which distinguishes it from the previous species «namely *A. obscuricornus*». Providing that my observations are correct, I can't find any more differences with certainty, because even the breadth of the abdomen and the length of the second and third segment of the antennae vary greatly.
To the granulated species belong the species *A. alternatus* Dall., and without doubt *A. abdominalis* Dall. and *A. rhombifer* Westw." **(Mayr 1868)**

"4. AMORBUS ANGUSTIOR, *C.H.* 410.
a. Australia. Presented by Sir J. Richardson." **(Walker 1871)**

"9. **A. angustior** WESTW. - *Physomerus angustior* WESTW. in HOPE, Cat. 2. p. 9. (1842). - *Amorbus angustior* DALL., List. 2. p. 410. 4. (1852); MAYR, Reis. Nov., Hem. p. 87. (1866).
Country: Australia." **(Stål 1873)**

"Subfam. AMORBINAE...
AMORBUS ANGUSTIOR. (Plate XXIX. fig. 2.)
Physomerus angustior Westw. in Hope Cat. ii. p. 9. (1842)
This species can be separated from *A. obscuricornis* Westw., to which it is closely allied, by the colour of the posterior tibiae. Dr. Mayr (Reise Novara, Hem. pp. 86-7) separates the species by the colour of the antennae, and by the presence or absence os a small black spot on the red upper surface of the abdomen. These characters are, however, both inconstant, and this distinctlion [distinctlion] «distinction» cannot be maintained. Westwood omitted to describe the colour of the posterior tibiae in his *A. angustior*, but the unique type is now figured...
SPECIES REQUIRING GENERIC REVISION...
Physomerus angustior Westw. loc. cit. p. 9 belongs to genus *Amorbus*." **(Distant 1901)**

"Physomerus angustior Westw. New Holland
Unique male Type. 17.43 mm long, pronotal humeral width 6.47 mm, maximum width across abdomen/connexivum 7.13 mm. Membrane barely surpassing the end of the abdomen.
Fig. 12 'scent gland' rim prominent. Ventrites with a longitudinal shallow depression not reaching distal ventrite.
Antennae 33-37.5-35-29 = 2.73-3.0-2.9-2.4...
Angustior-♂ hind femora proximally close to coxae etc.. with variable sized sparse maculae; distally maculae smaller and denser. Ridge with even-sized small maculae...
Angustior-N.H. Holotype ♂ agrees in coloration with key; hind femora with pale speckles, very pronounced proximally, distally consistently smaller speckles with what appears to be short adpressed hairs. Proximal speckles more or less rounded, distally "elongated".
Type labelled Amorbus angustior Westw. by Distant who also presumably put a red circular Type label on. All the types listed have a printed label of inordinate length:

TYPE
WESTW. (HOPE)
C. Hempt. 1842
Part II, p. 9
Distant P.Z.S.
1901, p. 325-335
Pl. xxix, Fig. 2.

This label is edged in red and was probably added by Holland in 1902 or thereabouts." **(Lansbury 1992 *in lit.*)**

Amorbus atomarius Stål

"3. **A. atomarius** STÅL. - Dully flavescent or ferrugineo-flavescent, infuscate above and nigro-punctate, puncta equipped with pale granules; antennae, on head above, on dorsum of abdomen, forward femora above, rear within, rear tibiae within from base beyond middle blackish; at fourth joint of antennae, lateral line of head, at apex of scutellum, two maculae or/rather [*vel*] connective of segments at/with forward fascia, sometimes even with discoidal maculae of dorsum flavescent; wings sub-fuscous vinaceous. ♂. ♀. Length 19-22, width of hemelytra 6½-7 mill.

♂. Abdomen not ampliate, dorsal apical segment rearwards subsinuate on either side, apex obtusely rotundate; genital segment subsulcate towards back, apex subsinuate; rear femora slenderly subfusiform, underneath within with some small tubercles placed in series, outside carina distinct denticulate, the apex equipped, endowed with quite distinct tooth; tibiae beneath more distinctly dilatate.

♀. Abdomen very lightly ampliate; genital dorsal segments almost equally long or posterior shorter than anterior, and apex obtusely sinuate «plural, not singular»; rear femora more slender, before the middle gradually becoming slender, moreover as with male; rear tibiae beneath more distinctly dilatate.

Country: northern Australia; Port Denison; Sydney (Mus. Holm.)

First joint of antennae barely, second more distinctly trigonal, fourth joint almost equal to third in length or a little longer. Thorax with forward sharp angles, projecting slightly towards the front, lateral margins turning pale, lateral angles somewhat obtuse, projecting slightly. Nigro-fuscous membrane. Chest distantly granulate-punctate. Abdomen, feet and antennae granulate.

dd. *Rear tibiae of either sex behind middle or almost in middle beneath angulate-ampliate or among females not angulate; rear femora of males fusiform.*

e. *Rear tibiae of either sex beneath angulate-ampliate; rear femora of males beneath soon behind middle ampliate into most obtuse angle; genital dorsal segments of females almost equally long, transverse.*" **(Stål 1873)**

Amorbus biguttatus Stål

"2. **A. biguttatus** STÅL. - Palely ferrugineo-flavescent; above fusco-ferrugineo-punctate; longitudinal abbreviate line of thorax and veins of corium levigate; rear macula of corium near interior angle flavescent; two black lines on head; membrane fuscous, inner basal angle darker; wings vinaceous; dorsum of abdomen fusco-ferrugineous, paler forward, two maculae of discus flavescent, sides of four rear segments nigro-maculate; rear femora behind middle or towards apex and middle fascia of rear tibiae fuscous; second, third and fourth segments equipped with connective common vitta, wide behind, narrowed directed towards front, black, ornate.

♀. Length 20, width of hemelytra 7, width of abdomen 8 mill.

♀. Abdomen lightly ampliate, genital dorsal segments of equal length, anterior apex very obtusely sinuate, posterior apex obtusely subangulate sinuate, more than twice as wide than long, rear femora slightly incrassate, straight, above barely perspicuously subcarinate, underneath outside obtusely carinate, carina granulate, denticulate towards the apex and apex equipped with sharp distinct tooth; rear tibiae straight or before middle almost curved, when seen on the side equally wide everywhere, not dilatate beneath, very minutely denticulate

Country: Port Denison Australia. (Mus. Holm.)

Stature of preceding, to which it is very close, with puncta of thorax and scutellum nonexistent or almost entirely absent, on outer part of corium however more distinct, granulate, with apical angle of thorax barely projecting, lateral angles straight, and not obtuse, macula of corium, marking of dorsum of abdomen [*pictura dorsi abdominis*], with rear tibiae of female straight, beneath before the middle lacking tooth and the rest very distinct [*distinctissima*]. Fourth joint of the antennae a little shorter than the third. Head and thorax in front indistinctly granulate, lateral margins of this crenulate. Scutellum levigate at apex, with two maculae at base quite levigate, sometimes indistinct, notate. Chest palely punctate. Venter and femora granulate with/at [*et*] discus. First joint of antennae barely trigonous, second smooth.

aa. *Bucculae less long; rostrum longer, first joint extended behind bucculae.*

b. *Apex of scutellum not incrassate.*

c. *Feet and venter distinctly granulate.*

d. *Rear tibiae of either sex a little before the middle angulate-ampliate and slightly curved; rear femora of sexes not quite conforming* [subconformibus], *among males a little thicker, the lower carina near apex equipped with distinct tooth.*" **(Stål 1873)**

Amorbus bispinus (Westwood)

"♂. Akin to the previous ones «namely *Physomerus affinis*, *P. angustior*, *P. subserratus* and *P. obscuricornis*». Brown, very minutely granulate, abdomen above in middle fulvous, antennae and feet black, trochanters whitish rear femora below armed with two teeth, rear tibiae at apex 7-serrated, abdomen's sides revealed.

Length of body in lines 8 «≡ 16.9 mm».

♀. Antennae and feet more refuscent [*Antennis pedibusque magis rufescentibus*], abdomen more rhombic; rear feet slender femora at apex armed with small spina.

Length of body in Lines 7 «≡ 14.8 mm». Lives in New Holland. "Swan River."" **(Westwood 1842)**

"11. **A. bispinus** WESTW. - *Physomerus bispinus* WESTW. in HOPE, Cat. 2. p. 9. (1842).

Country: Australia, Swan River " **(Stål 1873)**

"Subfam. AMORBINAE...
AMORBUS BISPINUS.
Physomerus bispinus Westw. in Hope Cat. ii. p. 9 (1842)...
SPECIES REQUIRING GENERIC REVISION...
Physomerus bispinus Westw. *loc. cit.* belongs to genus *Amorbus*." **(Distant 1901)**

"**Amorbus bispinus** Westw. I. Swan River, Westwood, Cotype." **(Blöte 1938)**

"Bispinus -Lectotype ♂ labelled by Distant with red circular Type label, handwritten label Amorbus bispinus Westw. and a printed 'Holland label'. The lectotype does not have a data label [S.R.] «[S.R.]». Femora of all legs uniformly dark purplish brown lacking large pale maculations on hind femora. Scent gland differentially colored from dark pitchy red/purple thorax.
Two Paralectotypes ♀♀ not seen by Distant from S.R. Pronotum, clavus and corium much paler than male. Hind femora pale reddish brown. Pro-meso and metathorax pale reddish gradually merging to pale yellow along margin of metasternum. Ventrites pale yellow. Scent gland not differentially colored." **(Lansbury 1992 *in lit.*)**

Amorbus hirticulus Dallas

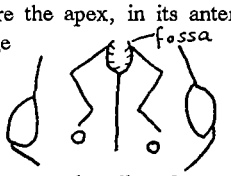
"2. AMORBUS hirticulus, n. s.
A. pale brownish above, punctate, subhirsute; chest ochre-coloured, punctate; femora becoming brown, tibiae testaceous; basal joint of the antennae becoming brown; 2nd and 3rd tawny, apical «joint» brownish, base testaceous. ♂?
Length in lines 10 «≡ 21.2 mm». «Latin portion»
Elongate ovate; above pale brown, thickly punctured with brown, and with a short, whitish hair accompanying each of the punctures. Head blackish towards the sides. Thorax with the lateral margins curved, somewhat reflexed. Scutellum with the tip pale. Coriaceous portion of the elytra with the basal half of the outer margin blackish; membrane brown, darker towards the inner basal angle. Abdomen wanting. Breast ochraceous, rather coarsely punctured, and with several short white hairs; mesosternum with two longitudinal black bands. Thighs pale brown, clothed with short whitish hairs, the posterior pair much thickened, fusiform, with only one or two minute teeth close to the apex; tibiae testaceous, brownish at the base, the posterior pair compressed, curved inwards a little behind the middle, and with an acute tooth at the same place on the inner margin; between this tooth and the apex are one or two minute denticulations; tarsi testaceous; claws brown, tipped with black. Rostrum reaching the anterior coxae, with the tip reposing in the canal of the front of the mesosternum; testaceous, with the tip black. Antennae with the first three joints nearly equal in length; basal joint brownish, second and third orange, last joint brown with the base testaceous.
a. N S.Wales. Presented by Dr. A. Sinclair. «English portion»" **(Dallas 1852)**

"2. AMORBUS HIRTICULUS, *C.H* 409.
a. New South Wales. Presented by Dr. Sinclair." **(Walker 1871)**

"14. **A. hirticulus** DALL. - *Amorbus hirticulus* DALL., List. 2 p. 409. 2. (1852).
Country: Eastern Australia." **(Stål 1873)**

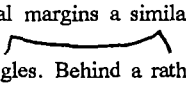
"**Amorbus hirticulus** Dall. I. ?." **(Blöte 1938)**

"*Amorbus hirticulus* Dallas 1852
Amorbus hirticulus is a ♂ although the abdomen has been lost (Large typical ♂ femora).
It is elongated oval and looks very like *alternatus* in shape and color. Head above and below, pronotum, scutellum, corium, and clavus shortly pilose, the hairs on the pronotum and coriaceous parts of the hemelytra located in small pits, the latter so arranged on the PN as to give an appearance of transverse ridges.
Head above normal in shape, the antennifers interiorly well separated, vertex with a longitudinal line medially reaching from just in front of the ocelli to just before the apex, in its anterior half widened into a sort of a fossa. In front of the ocelli a kind of raised zigzag ridge



Antennifers separated off by a somewhat oblique depressed valley from the rest of the head. Only three segments of the antennae remain, the first has a faint tendency to be quadrate in cross section but one axis is much longer than the other so that they also appear rather flattened.

Remaining two segments circular in cross section lengths in ascending order III-I-II.

Pronotum rather more elongate than in some of the other species, its anterior and anterolateral margins very narrowly marginate and crenulate (looking almost like a row of beads) and rather raised. Anterior margins gently concave behind the collum, anterior angles very shortly produced as a little lobe or triangle, the anterolateral margins almost straight. Lateral angles obtuse, posterolateral margins obtuse angulate rounding shortly onto the feebly concave posterior margin. Behind the anterior margin a narrow impression following the shape of the collar, paralleling the anterolateral margins a similar groove in its anterior third behind the point the anterolateral margin becoming elevate thus  reaching its greatest elevation at the lateral angles. Behind a rather vague wavy line between the lateral angles the very hind portion of the pronotum strongly depressed.
Scutellum and hemelytra seem fairly normal, membrane light brownish with concolorous veins slightly lightened very narrowly in its basal exterior half.
Beneath rostrum reaching a bit behind fore coxae and two longitudinal blackish lines one on either side of the midline, of the prosternum. Fore femora and mid femora with a preapical sharp spine. Hind femora moderately swollen with two smallish preapical spines anteriorly. All tibiae sulcate exteriorly, hind tibiae angled in just past the middle where on the inner side there is a single short spine followed shortly after by a small nodule, the tibiae are not expanded at this point.
Abdomen missing." **(Gross 1969 *in lit.*)**

Amorbus obscuricornis (Westwood)

"And also very much akin to the previous ones «namely *Physomerus affinis*, *P. angustior*, and *P. subserratus*» and perhaps a geographical variety, antennae black as pitch at base of joints 2 and 3, and the 4th entirely reddish, pronotum and hemelytra red-brownish the feet dark brown femora ♂ not thickened and in middle beneath angulate-dentate, and tibiae flattened and in the middle angulate at the internal margin behind the angle very serrated; ♀ abdomen a little broader; the rear feet slender femora black, small apical spine armed beneath, with red tibiae.
Length of body in lines 8 «≡ 16.9 mm». Lives in Van Diemen's Land." **(Westwood 1842)**

"5. AMORBUS obscuricornis.
Physomerus obscuricornis, *Hope, Cat.* 9 (1842).
a. Van Diemen's Land.
b. Van Diemen's Land. From Mr. Children's Collection.
c. Van Diemen's Land. From Mr. Hooker's Collection.
d. Van Diemen's Land. Presented by the Rev. T. Ewing.
e. ——. From Mr. Children's Collection.
f. N. Holland. Presented by Sir John Richardson, M D." **(Dallas 1852)**

"*a)* Granulate species...
A. OBSCURICORNIS Westw.
Physomerus obscuricornis Westw Hope Cat. II, p. 9 (1842).
Amorbus obscuricornis Dall. List Hem. II, p. 410 (1852).
New Holland.
This species species shows on the red dorsal side of the abdomen only at the sixth segment a more or less large quadratic black spot, but can be distinguished from the previous species «namely *A. rubiginosus*» by its red colour of the body and the dark antennae." **(Mayr 1868)**

"5. AMORBUS OBSCURICORNIS, *C.H.* 410.
a, b. Australia. Presented by Sir J. Richardson.
c, d. Tasmania. Presented by the Rev. T. Ewing.
e, f. Tasmania. From Dr. Hooker's collection.
g, h. Tasmania. From Mr. Children's collection.
i. Tasmania. Presented by W.W. Saunders, Esq.
j. New South Wales. Presented by W.W. Saunders, Esq." **(Walker 1871)**

"6. **A. obscuricornis** WESTW. - *Physomerus obscuricornis* WESTW. in HOPE, Cat. 2. p. 9. (1842). - *Amorbus obscuricornis* DALL., List. 2. p. 410. 5. (1852); MAYR, Reis. Nov., Hem. p. 86. (1866).
Country: Australia. (Mus. Holm.)
cc. *Venter and feet lacking granules or with these very indistinctly granulate; rear feet less apart; abdomen of either sex broad; juga tuberculate below antenna-bearing tubercles, projecting slightly; basal joints of antennae triangular.*" **(Stål 1873)**

"SPECIES REQUIRING GENERIC REVISION...
Physomerus obscuricornis Westw. *loc. cit.* belongs to genus *Amorbus.*" **(Distant 1901)**

"**Amorbus obscuricornis** Westw. I. Van Diemensland, Westwood, Cotype. - 2. New Holland, Deyrolle. - 3-6.

Melbourne, F. Müller." **(Blöte 1938)**

"Physomerus obscuricornis Westw. V.D.L.
Male 17.098 mm long, maximum width across abdomen/connexivum 7.138 mm. Female (Type labelled by Distant) 16.434 mm long, maximum width across abdomen/connexivum 7.47 mm.
Female much more rhomboid than male.
Figs. 1-6 male. Fig. 5 enlarged detail of elevated rim of 'scent gland'. Fig. 6 hind femora 'dorsal margin' slightly sinuate and appearing obtusely carinate.
Fig. 7 female, rim of 'scent gland' slightly elevated. All the legs and antennae of the female are missing
Antennae of male 32-36-32-missing = 2.65-2.98-2.65 mm....
Obscuricornis- ♂ figured and repinned. Hind femora proximally with even sized maculae becoming progressively denser and smaller distally-anterior ridge with many moderately sized maculae...
Obscuricornis-V.D.L. Lectotype ♂, Underside of thorax pitchy red-anterior margin of scent gland pale yellow/cream and very conspicuous. Hind femora lacking large pale blotches as found on "rubiginosus" This is the male I figured and repinned- am sure it was not examined by Distant.
Paralectotype ♀ lacks all legs and antennae. Underside pale reddish brown-scent gland not differentially colored from thorax. Distant labelled female with circular red Type label, handwritten label (Distant) Amorbus obscuricornis Westw. and a printed 'Holland label'.
It does seem possible that this pair may not be conspecific. The male is not con-specific with rubiginosus unless Guerin's species is extremely variable. The males of the two rubiginosus mentioned under Affinis do not have the scent gland differentially pigmented as does the male of obscuricornis." **(Lansbury 1992 *in lit.*)**

Amorbus planus Walker

"11. AMORBUS PLANUS.
Female. *Tawny, tomentose, elliptical; antennae longer than half of the body; prothorax very finely scabrous, subsulcate longitudinally, sides subcrenulate, subretuse, rear angles obtuse; scutellum striped with black base; abdomen red, six-striped with black with continuity broken; rear femora almost incrassate, below serrate in double rows, rear tibiae below at the middle are almost-dilatate, almost angulate, serrate towards the apexes; membrane brown.* Male. - *Thinner; black disc on abdomen, with four red streaks crosswise; rear tibiae angulate below and almost dilatate.* «Latin portion»
Female. Tawny, tomentose, elliptical. Rostrum short, its tip in a groove near the fore coxae. Antennae rather more than half the length of the body; joints from the first to the fourth successively decreasing in length. Prothorax very minutely scabrous, with an indistinct longitudinal furrow and a slight transverse ridge near the hind border; sides straight, slightly crenulated and retuse; hind angles obtuse, not prominent. Scutellum with a black basal band. Dorsum of the abdomen red, with six black bands, which, with the exception of the fifth, are interrupted on each side. Femora beneath with a subapical spine. Hind femora slightly incrassated, minutley serrated on each side beneath. Hind tibiae slightly dilated and angular beneath at somewhat less than half the length from the base, minutely serrated from thence to the tips. Fore wings with a brown membrane. Hind wings lurid-cinereous. Length of the body 10½ lines «≡ 22.2 mm».
Male Narrower than the female. Dorsum of the abdomen with a black disk, which has four transverse red streaks; sides with black spots. Hind femora rather more incrassated than those of the female. Hind tibiae slightly dilated beneath along the whole length, the angle more prominent than that of the female Length of the body 8½ lines «≡ 18.0 mm».
a, b. Australia. From Mr. Macgillivray's collection. «English portion»" **(Walker 1871)**

Amorbus rhombeus (Westwood)

"♂ Akin to the previous ones «namely *Physomerus affinis, P. angustior, P. subserratus, P. obscuricornis, P. bispinus* and *P. rhombifer*» but more robust, rhombic abdomen with revealed sides, rear femora swollen not angulate-dentate, barely spinose towards the apex, tibiae a little curved back, spina within in middle [*in medio interne spina*], and behind spina with numerous minute serrulae, armed with rear femora black as pitch, tibiae paler.
Length of body in lines 9 «≡ 19.1 mm». Width of abdomen in lines 4 «≡ 8.5 mm». Lives on Melville Island." **(Westwood 1842)**

"7. AMORBUS rhombeus.
Physomerus rhombeus, *Hope, Cat.* 9 (1842).
a. —. From Mr. Children's Collection.
b. —." **(Dallas 1852)**

"7. AMORBUS RHOMBEUS, *C.H.* 411.
a, b. Swan River. From Dr. Bacon's collection.
c. New South Wales. Presented by W.W. Saunders, Esq.
d. —? From Mr Children's collection.
e, f. —?" **(Walker 1871)**

"13. **A. rhombeus** WESTW. - *Physomerus rhombeus* WESTW. in HOPE, Cat. 2. p. 10. (1842). - *Amorbus rhombeus* DALL., List. 2. p. 411. 7. (1852).
Country: Melville Island." **(Stål 1873)**

"Subfam. AMORBINAE...
AMORBUS RHOMBEUS.
Physomerus rhombeus Westw. in Hope Cat. ii. p. 10 (1842).
Amorbus rhombifer Dall. (*nec* Westw.) List Hem. ii. p. 411. n. 8 (1852).
A. rhombifer and *A. rhombeus* are very closely allied and doubtfully distinct. Beyond a generally darker hue and greater incrassation of the posterior femora in the male of *A. rhombeus*, there is scarcely a character to separate the two forms...
SPECIES REQUIRING GENERIC REVISION...
Physomerus rhombeus Westw. *loc. cit.* p. 10 belongs to genus *Amorbus*." **(Distant 1901)**

"Rhombeus-Lectotype ♂ M.I. red circular Type label, also labelled by W.L.D. «W.L. Distant» Amorbus rhombeus Westw. Printed 'Holland label'. Femora of all legs purplish brown. Surface faintly granular, slightly pilose (less than rhombifer). Underside of thorax pale reddish brown, ventrites rather more yellow, scent gland not differentially colored. Ventral margin of hind femora obtusely carinate, sinuate becoming obsolete distally. Mid femora with one large and one small spine distally." **(Lansbury 1992 *in lit.*)**

Amorbus rhombifer (Westwood)

"♂. Akin to the previous ones «namely *Physomerus affinis*, *P. angustior*, *P. subserratus*, *P. obscuricornis* and *P. bispinus*». However differs in that size is more slender; abdomen rhombic thorax two times wider sides very much revealed, rear femora not angulate-dentate. Brown, granulose, at first joint of the antennae with dark femora; front femora below at apex 1-spinose, rear swollen below not angulate-spinose, armed with two small spinae below, rear tibiae barely curved, behind middle armed with small spina internally, and behind the spina internally not serrulate, light yellow.
Length of body in lines 9 «≡ 19.1 mm». Width of body in lines 4½ «≡ 9.5 mm».
♀. Very similar, abdomen little more rhombic, and rear feet slender, tibiae upright.
Length of body in lines 11 «≡ 23.3 mm». Width of body in lines 5½ «≡ 11.6 mm». Lives in New Holland." **(Westwood 1842)**

" 8. AMORBUS rhombifer.
Physomerus rhombifer, *Hope, Cat.* 9 (1842).
a. New Holland.
b Philippine Islands. Presented by J.C. Bowring, Esq." **(Dallas 1852)**

"8. AMORBUS RHOMBIFER, *C.H.* 411.
a. Australia.
b. New South Wales. Presented by W.W. Saunders, Esq.
c. Philippine Isles. Presented by J.C. Bowring, Esq." **(Walker 1871)**

"12. **A. rhombifer** WESTW. - *Physomerus rhombifer* WESTW. in HOPE, Cat. 2. p. 9. (1842). - *Amorbus rhombifer* DALL., List. 2. p. 411. 8. (1852).
Country: Australia." **(Stål 1873)**

"Subfam. AMORBINAE...
AMORBUS RHOMBIFER.
Physomerus rhombifer Westw. in Hope Cat. ii. p. 9 (1842).
Amorbus rhombeus Dall. (*nec* Westw.) List Hem. ii. p. 411. n. 8 (1852)...
SPECIES REQUIRING GENERIC REVISION...
Physomerus rhombifer Westw. *loc. cit.* belongs to genus *Amorbus*." **(Distant 1901)**

"**Amorbus rhombifer** Westw. I. New Holland, Westwood, Cotype." **(Blöte 1938)**

"Rhombifer- Lectotype ♂ no data label. Distant red circular Type label, label in W.L.D. «W.L. Distant» handwriting Amorbus rhombifer Westw.
Printed Holland label.
Hind femora finely pilose; ventral margin with a longitudinal band margined with minute rounded projections. Ventral margin distally with two spines. Mid femora with one large & one small spines distally. Scent gland not differentially colored from thorax. Westwood also mentions a female from N.H. Have a female which may be the specimen. Underside uniformly pale creamy yellow. Legs purplish brown with slightly coarser pilosity than male." **(Lansbury 1992 *in lit.*)**

Amorbus robustus Mayr

"**Amorbus** Dall.

A. robustus n. sp. Length of body 22mm., width of pronotum [*pronoti*] 8.3mm. Reddish-testaceous, the upper part of the body and of femora olive-black, antennae orange, margins of pronotum antico-lateral [*antico-lateralibus*], puncta and costae of the corium and clavus, at the rear of the corium a broad yellow margin [*margineque corii postico lato flavis*], the venter rubrotestaceous above with 2 black vittae; densely yellow-granulate shoulders porrect sharp [*dense flavo-granulatus humeris porrectis acutis*]. Sydney." **(Mayr 1865)**

"*a)* Granulate species.

A. ROBUSTUS Mayr.

FIG. 17.

Amorbus robustus Mayr Verh. zool. bot. Ges. 1865, p. 432.

♀ *Length: 22^{mm}. Brunneus-testaceous, upper part of the body and the femora are olive-blackish, antennae orange, lateral margins of the pronotum, puncta and costae of corium and clavus, and rear broad margin of the corium are tawny, venter reddish-testaceous above with 2 black vittae; densely tawny-granulate; shoulders porrect acute; rear tibiae dilatate at basal part.* «Latin portion»

Sydney in New Holland.

Doesn't shine, brownish-reddish-yellow, on the dorsal side blackish-brown, under certain lighting conditions with a weak greenish sheen; the antennae are orange-red to coral red, the last segment of the antennae has a brownish colour; the lateral edges of the head and the pronotum are yellow, dots are scattered across the elytra and the back edge of the corium is a dirty yellow. The lateral edge of the wing cover is yellow-brown and the abdomen is red-yellow on the dorsal surface and features two black lines going across the centre, on the dorsal side the four front femora are brownish and the back femora black. The back tibiae are brownish-red-yellow reaching just over half the basal length. The distal half and tarsi are yellow. The whole body is densely covered with little light-yellow grains, which causes the strange colouring on the dorsal side of the body. The base of the tylus is seen from above as a small round area between the antennae. The first segment of the antennae is 3.6, the second 3.9, the third 4, and the fourth 3 8mm. in length. The pronotum is at the anterior edge only 2.2mm. wide, and 8.3mm. wide in the shoulder region. The shoulders stick out, triangular, rather pointy and with 90° angles. The posterior femora are thickened and have on their distal half a large, wide, somewhat triangular, blunt tooth, as well as show a much sharper but smaller tooth closer to the knee joint. There are several very small teeth located in between these two larger teeth. The posterior tibiae are flat at their basal half, rather thick and possess a larger tooth in the centre region beyond which the tibiae narrow down towards the tarsal joint, which is also covered on the inner side with little teeth. «German portion»" **(Mayr 1868)**

"10. AMORBUS ROBUSTUS.

robustus, *Mayr, Verh. Zool. Bot. Gesell. Wien.* xv. 432; *Hem.* 85.

Sydney." **(Walker 1871)**

"4. **A. robustus** MAYR. - *Amorbus robustus* MAYR, Verh. z.-b. Ges. Wien. 15. p. 432. (1865); Reis. Nov., Hem. p. 85. f. 17. (1866).

Country: northern Australia, Cape York (Mus. Holm.)

ee. *Rear tibiae of females straight, beneath not angulate; rear femora of males longer* [longius] *behind middle ampliate into angle or tooth.*" **(Stål 1873)**

"**Amorbus robustus** Mayr. I. New Holland, Deyrolle." **(Blöte 1938)**

Amorbus rubicundus Stål

"FAM. MICTIDAE.

31. **Amorbus rubicundus.**

Above roughly punctate, with antennae and feet ferruginous, tibiae thinned out; abdomen on both sides very rotundate-dilatate, underneath indistinctly [*obsolete*]. ♂♀. Length 18-20, width 9-10 millim.

Native land· New Holland (Sydney).

Narrower than *A. rubiginosus*, abdomen however much more dilatate, thorax longer, colour more indistinct. Head subelongate-quadrate, at apex deeply emarginate, at the middle lengthwise sulcate, between the eyes equipped with foveola, darkly ferruginous. Antennae shorter than the body by roughly a third, indistinctly ferruginous, basal joint darker, second and third of similar length [*subaequilongis*]. Thorax of similar length [*subaequilongus*] at rear width, to the front [*antice*] lightly sinuate, sides erect, subcrenulate, at the rear widely subrotundate, in the front subdeclive, towards the rear crosswise narrowly raised [*posterius transversim anguste subelevatus*], rugose-punctate, ferruginous, towards the front between the margin fuscescent. Scutellum triangular, roughly punctate, ferruginous, more indistinct at bottom of apex. Hemelytra ferruginous, roughly quite densely punctate, membrane copperish-dark. Beneath palely flavotestaceous, chest roughly quite densely punctate, abdomen on either side very rotundate-dilatate, indistinctly punctate, above towards the sides ferruginous, roughly punctate. Feet ferruginous, tibiae and tarsi testaceous, anterior femora towards apex armed with two spines below, smaller apically [*apicali minore*], rear femora quite incrassate, within somewhat

compressed-ampliate, subtuberculate, (♂) either simple, towards the apex equipped with two spinules (♀); rear tibiae in ♂ within at middle angulate-subdilate, towards the apex serrulate." **(Stål 1859)**

"*b)* Spotted species.
A. RUBICUNDUS Stål.
Amorbus rubicundus Stål Eug. Resa, Ins. p. 232 (1858).
Sydney in New Holland.
The general body shape is similar to the previous species «namely *A. robustus*, *A. rubiginosus*, *A. obscuricornis* and *A. angustior*», but can easily be separated from it by the absence of small grains and the presence of spotting and the males haven't got a triangular tooth in the centre region of the posterior femora.
To this group most probably belong *A. hirticulus* Dall. and *A. discolor* Dall." **(Mayr 1868)**

"9. AMORBUS RUBICUNDUS.
rubicundus, *Stal, Eug. Resa, Hem.*232. *Mayr, Hem.* 87.
Sydney." **(Walker 1871)**

"7. **A. rubicundus** STÅL. - *Amorbus rubicundus* STÅL, Freg. Eug. resa., Ins. Hem. p. 232. 31. (1859).
Country: Australia, Sydney. (Mus. Holm.)
bb. *Apex of scutellum incrassate.*" **(Stål 1873)**

"**Amorbus rubicundus** Stål. I. Australia, Dohrn. - 2-3. New South Wales, Staudinger 1936." **(Blöte 1938)**

Amorbus rubiginosus (Guérin-Méneville)

"CORÉE ROUILLÉ, *Coreus rubiginosus*. Guér. - *Darkly ferruginous; paler beneath. Thorax triangular, forward nigro-bimaculate. Head dark at base and apex. Rear femora incrassate, below unidentate.* - Length 19 mill., l. 7 m. «Latin portion»
It is entirely red-rust coloured, darker above, paler below. The antennae are almost of the length of the body, with the first and last joints brown. The head is brown, finely grained. The thorax is of triangular shape, finely grained above, somewhat edged and denticulate on the sides, with a raised line, transverse on the posterior edge, and two brown stains in front. The scutellum is triangular, equilateral. The elytra are very finely grained; their membranous portion is of somewhat metallic brown. The legs are of the same colour as the top, the anterior and intermediate are not very strong, equipped above and towards the extremity with a quite small tooth. The posterior thighs are very swollen, equipped with a large tooth above; their legs are somewhat curved on the outside with quite a strong angle on the inside and at the middle of their length, they are denticulate from this point to the extremity. The sides of the abdomen above are marked, at the suture of the segments, with a little trie[1] [trie]. All the above part is yellowish-ferruginous. - From Port Jackson, in New Holland. «French portion»" **(Guérin-Méneville 1830)**

[1] 'trie' is an old, rare word said by dictionaries to mean 'selection' or 'pigeon loft'. Experts within the French Department at the University of Tasmania were not able to provide a meaningful definition for this word.

"3. AMORBUS rubiginosus.
Coreus rubiginosus, *Guér. Voy. Coq. Zool.* ii. *Ins.* 173 (1830).
Physomerus affinis, *Hope, Cat.* 9 (1842).
a. N. Holland.
b. N. Holland. Presented by the Entomological Club.
c. Port Essington. From Mr. Gould's Collection." **(Dallas 1852)**

"*a)* Granulate species...
A. RUBIGINOSUS Guér.
Coreus rubiginosus Guér. Voy. Coq. Ins. p. 173 (1838).
Amorbus rubiginosus Dall. List Hem. II, p. 410 (1852).
Physomerus affinis Westw. Hope Cat. II, p. 9 (1842).
Sydney in New Holland.
This species is recognisable by its abdomen, the first four segments and a spot on the fifth segment are coloured red under the hard wing cover on the dorsal side, while the larger part of the fifth and sixth segment is black. The whole of the connexivum and the rest of the body is dark brown, only the edges of the segments are yellow. With all examined samples I found that the second segment of the antennae are at the basal end more or less brownish." **(Mayr 1868)**

"3. AMORBUS RUBIGINOSUS, *C.H.* 410.
a. Australia. Presented by the Entomological Club.
b, c. Port Essington. From Mr. Gould's collection.
d. Moreton Bay. Presented by — Gibbons, Esq.

e, f. Australia." **(Walker 1871)**

"5. **A. rubiginosus** GUÉR. - *Coreus rubiginosus* GUÉR., Voy. Coq., Ins. p. 173. (1838). - *Physomerus affinis* WESTW. in HOPE, Cat. 2. p. 9. (1842). - *Amorbus rubiginosus* DALL., HST. 2. P. 410. 3. (1852); MAYR, Reis. Nov., Hem. p. 86. (1866).
Country: Australia, Moreton Bay, Adeliade. (Mus. Holm.)" **(Stål 1873)**

"**Amorbus rubiginosus** Guér. I-2. Adeliade, Felder. - 3. New Holland, Westwood, Cotype of *Physomerus affinis* Westw." **(Blöte 1938)**

Amorbus subserratus (Westwood)

"Very much akin to preceding narrower one «namely *Physomerus angustior*», differs however in body a little shorter and wider; colour darker, rear femora not very thickened, tibiae behind middle angle of internal margin 4-serrate. ♂
Length of body in lines 7¾ «≡ 16.4 mm». Lives on "Melville Island."" **(Westwood 1842)**

"10. **A. subserratus** WESTW. - *Physomerus subserratus* WESTW. in HOPE, Cat. 2. p. 9. (1842)
Country: Melville Island." **(Stål 1873)**

"Subfam. AMORBINAE...
AMORBUS SUBSERRATUS. (Plate XXIX. fig. 5.)
Physomerus subserratus Westw.
The only really distinguishing feature of this species from the above «namely *A. angustior*» is found in the character described by Westwood as "tibiae behind middle angle of internal margin 4-serrate." ["*tibiisque pone angulum medium marginis interni 4-serratis.*"]...
SPECIES REQUIRING GENERIC REVISION...
Physomerus subserratus Westw. *loc. cit.* belongs to genus *Amorbus*." **(Distant 1901)**

"Physomerus subserratus Westw. Melville Island
Unique male type. 17.43 mm long, pronotal humeral width 6.55 mm,
width across abdomen/connexivum 7.3 mm.
Male figs. 23-28. 'scent gland' small compared with other species.
Membrane clearly extending beyond the end of the abdomen.
Male antennae 32-35-37-31 = 2.65-2.90-3.0-2.57 mm...
Subserratus-M.I. Holotype ♂, Distant put a red circular Type label and a handwritten label Amorbus subserratus Westw. and it also has a printed Holland label. The hind femora with prominent raised maculae in 4-5 clearly defined rows amongst the much smaller nodules." **(Lansbury 1992 *in lit.*)**

Appendix 2

The following details summarise the locality, host plant (where provided), date and collector information gleaned from labels belonging to specimens from collections other than the author's (see Chapter 2 for key to collection abbreviations). (N.B. it is only possible to sex *G. tasmanicus* adults, *Amorbus* spp. adults and V instar nymphs.)

Gelonus tasmanicus (Le Guillou)

Material examined. 1 ♀, *Syromastes tasmanicus* (lectotype) (head missing), Hobart, date missing, Le Guillou (MP). New South Wales: 1 ♂, Alpine Ck, nr Kiandra, 9.i.1964, MacKerras (DASUT); 1 ♀, Happy Jack River Gorge, Snowy Mts, 28.xi.1956, I.G. Filmer (QM); 1 V instar, 3 ♂♂, 4 ♀♀, Pilot Hill, Bago Forest, 3.iii.1957, 5.iii.1957, 6.iii.1957, 12.iii.1957, 14.iii.1957, T.G. Campbell; 1 ♀, Mt Dowe, Nandewar Ra, 3.xi.1967, K.H.L. Key; 2 V, 2 ♂♂, 1 ♀, Dickey Cooper Cr, summer 1982-1983, summer 1984-1985, L.R. Fox; 4 ♂♂, 3 ♀♀, Pilot Hill, *E. delegatensis*, 13.x.1981, C.P. Ohmart; 3 ♂♂, 2 ♀♀, Pilot Hill, *E. delegatensis*, 12.ii.1981, C.P. Ohmart; 1 ♀, Kosciusko Nat. P., 26.x.1979, A. Rawson; 5 ♂♂, 1 ♀, Dainers Gap, *E. pauciflora*, 4.xii.1973, P. Morrow; 3 ♂♂, Dainers Gap, 22.xi.1973, *E. pauciflora*, P. Morrow; 1 ♀, Dainers Gap, *E. pauciflora*, 7.xi.1972, P. Morrow; 2 ♀♀, Dainers Gap, *E. pauciflora*, 23.x.1973, P. Morrow, 1 ♀, Dainers Gap, *E. pauciflora*, 6.xi.1973, P. Morrow; 1 ♂, 2 ♀♀, Dainers Gap, *E. pauciflora*, 13.xii.1973, P. Morrow; 1 ♂, 1 ♀, Dainers Gap, *E. pauciflora*, 28.xi.1972, P. Morrow; 2 ♂♂, 1 ♀, Dainers Gap, *E. pauciflora*, 29.xi.1972, P. Morrow; 2 ♂♂, 1 ♀, Dainers Gap, *E. pauciflora*, 5.xii.1972, P. Morrow; 1 ♂, 1 ♀, Dainers Gap, *E. perriniana*, 22.xi.1973, P. Morrow; 1 ♂, Dainers Gap, *E. pauciflora*, 9.iii.1973, P Morrow; 1 ♀, Dainers Gap, *E. pauciflora*, 14.xi.1972, P. Morrow; 1 ♂, 2 ♀♀, Dainers Gap, *E. pauciflora*, 22.xi.1972, P. Morrow; 1 ♂, Dainers Gap, *E. pauciflora*, 13.iii.1973, P. Morrow; 1 ♂, 1 ♀, Dainers Gap, *E. pauciflora*, 21.ii.1973, P. Morrow (ANIC). Tasmania: 3 ♂♂, 2 ♀♀, P.P Triabunna, 12.ii.1972, J.L. Madden; 3 ♂♂, P.P East Coast, xi.1972, J.L. Madden; 1 ♂, Chip Rd, i.1973, J.L. Madden; 1 ♂, Sandy Bay, 20.ix.1973, M. Thompson; 1 ♀, Dunalley, 28.i.1986, A. Leon; 1 ♀, West Launceston, ix.1974, M. Wells; 1 ♀, Myrtle Bank, 30.xi.1992, S. Lisson; 1 ♀, Sandy Bay, xi.1993, M. Connell; 1 ♀, Richmond, 16.vi.1992, I. Green; 1 ♀, Midway Point, 23.viii.1992, T. Botwright; 1 ♀, Notley Hills, 3.i.1971, C. Miller; 1 ♂, Waterworks, 27.x.1987, H. Henning; 1 ♀, Hamilton, 14.ii.1992, A.J. Marshall; 1 ♀, Christ College, iii.1972, P. Brignell; 1 ♂, Howrah, 6.x.1979, T. Groom; 1 ♂, Lenah Valley, xi.1984, J. Sewell; 1 ♂, Sandy Bay, 5.xi 1981, B. Eckel; 1 ♀, South Hobart, 6.xi.1990, N. Doran; 1 ♂, Battery Point, 27.x.1993, K. Millar; 1 ♀, Dynnyrne, 6.xi 1976, G.H Braid, 3 ♂♂, 2 ♀♀, Snug Plains, 8.iii.1979, J L. Madden (DASUT); 3 ♂♂, Camden Mtn, 8.ii.1963, K.L. Taylor; 1 ♂, Maydena, 27.xi.1963, R. Greaves; 1 ♂, North Head, Pieman R, 29.xii.1953, I. Rowley; 1 ♂, Geeveston, 15.iii.1962, K.L. Taylor; 1 ♀, Mersey Valley, 23.i.1969, K.L Taylor (ANIC); 1 ♀, Mersey River, Liena, 16.xi.1972, A. Neboiss; 1 ♀, National Park, i.1933, F.E. Wilson; 1 ♂, Port Arthur, 3 xii.1933, D. Mahony; 1 ♂, Bluff Hill, Arthur River, 30.xi 1974, A. Neboiss; 1 ♂, Derwent River, 7.xi.1972, A. Neboiss; 1 ♂, Ulverstone, date missing, Lea; 1 ♀, Hobart, date missing, Lea; 2 ♂♂, 1 ♀, King Island, i.1907, J A. Kershaw; 2 ♂♂, Ridgeway, 10.x.1948, C. Oke (MV); 2 adults, Grove, 15.x.1971, collector missing; 1 adult, 1 ♀, Grove, 16.xi.1971, collector missing; 1 adult, 1 ♀, Florentine Valley, 27.xi.1977, collector missing, 1 ♀, Hobart, date missing, collector missing; 1 ♂, Florentine Valley, 27.xi.1972, collector missing; 1 ♀, Greens Beach, on *Eucalyptus*, 28.xi.1961, collector missing; 1 ♀, Grove, 18.x.1971, collector missing; 1 ♀, Grove, 10.xii.1973, collector missing; 1 ♂, 1 ♀, Copping, 27.x.1937, collector missing; 1 ♀, Lindisfarne, on *Lomandra longifolia*, 6.v.1963, collector missing; 2 ♂♂, Margate, 7.xi.1935, collector missing; 1 ♀, Yellow Marsh, *Poa*, 17.iii.1989, L. Hill (TDPIF); 2 ♂♂, Florentine Valley, *E. regnans*, 23.x.1974, H. Elliott; 1 ♂, 1 ♀, Florentine Valley, 9.xi.1977, H. Elliott; 4 ♂♂, 4 ♀♀, Florentine Valley, *E. regnans*, 20.xi.1974, H. Elliott; 1 ♂, Tower Hill, *E. obliqua*, 14.xii.1984, H. Elliott; 2 ♂♂, 1 ♀, Camden, *E. delegatensis*, 6.xi.1974, H. Elliott; 2 ♂♂, 2 ♀♀, Goulds Country, 28.x.1988, H. Elliott; 3 ♂♂, Goulds Country, 1 xii.1988, H. Elliott; 1 ♀, Lake Leake, *E. delegatensis*, 16.iii.1982, H. Elliott; 1 ♂, Woodsdale, *P. juniperana*, 12.x.1977, H. Elliott; 1 ♀, Lake Leake, *E. dalrympleana*, 17.xi.1977, H. Elliott; 1 ♀, Lake Leake, *E. delegatensis*, 18.iv.1977, H. Elliott; 1 ♀, Bicheno, *E. viminalis*, 14.xi.1979, H. Elliott; 1 ♂, Lake Leake, *E. delegatensis*, 10.iii.1978, H. Elliott; nymphs, adults, Geeveston, *Eucalyptus*, 1992, R. Bashford, nymphs, Woodsdale, *Eucalyptus*, 1992, R. Bashford; nymphs, Sidling, Scottsdale, *Eucalyptus*, 1992, R. Bashford; nymphs, adults, Evercreek, Fingal, *Eucalyptus*, 1992, R. Bashford; nymphs, adults, Arm River, Mersey, *Eucalyptus*, 1992, R. Bashford; nymphs, adults, Christmas Hills, Smithton, *Eucalyptus*, 1992, R. Bashford; nymphs, adults, Smiths Plains, Devonport, *Eucalyptus*, 1992, R. Bashford; adults, Lake Kara, Burnie, *Eucalyptus*, 1992, R. Bashford (FT); 1 V, Maggs Mt, 17.ii.1975, R.H. Green; 2 V, 1 ♂, Maggs Mt, on *Eucalyptus*, 18.ii.1975, R.H. Green; 1 ♂, 2 ♀♀, Maggs Mt, on *Eucalyptus*, 11.xi.1975, R.H. Green; 1 ♀, Maggs Mt, 10.xii.1975, R.H. Green; 84 II, 36 III, 11 IV, 1 ♂, 1 ♀, Maggs Mt, on *Eucalyptus*, 13.i.1976, R.H. Green; 1 II, Maggs Mt, on *Eucalyptus*, 20.i.1977, R.H. Green; 1 ♀, Lake St. Clair, v.1980, B. McCausland; 1 II, 5 III, 4 IV, 5 V, 1 ♀, Maggs Mt, on *Eucalyptus*, 25.ii.1986, R.H. Green; 1 II, 3 III, 4 IV, 12 V, 5 ♂♂, 2 ♀♀, Maggs Mt, on *Eucalyptus*, 27.ii.1986, R.H. Green; 1 III, 2 V, 3 ♂♂, 1 ♀, Maggs Mt, on *Eucalyptus*, 18.iii.1987, R.H. Green; 4 ♂♂, 1 ♀, Maggs Mt, on *Eucalyptus*, 11.iv.1988, R.H. Green; 1 II, 1 III, 4 IV, 7 V, 3 ♂♂, Maggs Mt, on *Eucalyptus*, 23.ii.1989, R.H. Green; 1 ♂, 1 ♀, Maggs Mt, on *Eucalyptus*,

7.iv.1989, R.H. Green; 4 ♂♂, Maggs Mt, on *Eucalyptus*, 8.iv.1989, R.H. Green (QVM). Australian Capital Territory: 1 ♂, 1 ♀, Fishing Gap, 22.ii.1964, K.H.L. Key; 1 ♂, Blundells, 11.x.1950, T.G. Campbell; 1 ♂, Blundells, 22.i.1931, J.W. Evans; 1 ♂, Bulls H, *E. dalrympleana*, 18.x.1971, K.O. H.M.; 1 ♂, Bulls, *E. pauciflora*, 20.xii.1971, H.M. K.O.; 2 ♂♂, 4 ♀♀, Bulls Hd, *E. pauciflora*, 20.ii.1973, K.O. + A.M.; 1 ♀, Bulls H, *E. pauciflora*, 28.iii.1972, K.O. + A.A.; 1 ♂, 2 ♀♀, Bulls H, *E. pauciflora*, 26.x.1971, K.O. & H.M.; 1 ♂, Bulls Hd, *E. pauciflora*, 6.iii.1973, K.O. H.M.; 1 ♂, Bendora, *E. delegatensis*, 23.x.1972, K.O. + A.M.; 1 ♂, Bendora, *E. delegatensis*, 19.xii.1972, K.O. + H.M.; 1 ♀, Bulls, *E. pauciflora*, 14.xii.1971, H.M. K.O.; 1 ♀, Bulls Hd, *E. dalrympleana*, 28.iii.1973, K.O. + H.M.; 1 ♂, Bulls Hd, *E. dalrympleana*, 23.x.1972, K.O. + A.M.; 1 ♂, Bulls Hd, *E. dalrympleana*, 20.ii.1973, K.O. + A.M.; 1 ♂, 1 ♀, Bulls H, *E. dalrympleana*, 26.x.1971, K.O. H.M.; 1 ♀, Bulls Hd, *E. dalrympleana*, 27.ii.1973, K.O. + A.M.; 1 ♂, Bulls H, *E. dalrympleana*, 18.x.1971, H.M. K.O.; 1 ♂, Bulls, *E. pauciflora*, 30.xi.1971, H.M. + K.O.; 1 ♂, Mt Ginini, 24.xi.1981, I.D. Naumann; 1 ♀, Gibraltar Creek, 18.x.1967, Z. Liepa (ANIC). Victoria: 2 ♂♂, Mt Buller, 1.x.1961, L.D.C. (VAIC); 1 ♂, Connor Plains, 20-29.xii.1967, A. Neboiss; 1 ♂, 6 ♀♀, Howqua River, 30.xi.1971, Neboiss; 1 ♂, 1 ♀, Siberia Gap, *E. regnans*, 18.i.1968, F.N.; 1 ♂, Mt Howitt, Jan-Feb.1972, K.G. Simpson; 1 ♀, Upper Kiewa, 27.xii.1958, Coghill; 2 ♂♂, 1 ♀, West Warburton, 22.iii.1924, J.E. Dixon; 1 ♂, Victoria, date missing, J.E. Dixon; 1 ♂, Gippesland, 10.ii.1923, collector missing; 2 ♂♂, Gembrook, date missing, collector missing; 2 ♀♀, Cape Otway Forest, 12.ii.1917, J.E. Dixon; 2 ♂♂, 1 ♀, Langwarrin, 17.ii.1924, J.E. Dixon; 1 ♂, Springvale, date missing, collector missing; 1 ♂, 1 ♀, Morang, 6.xii.1953, Nebioss; 1 ♀, Omeo, 30.i.1957, A.N. (MV).

Acantholybas longulus Breddin

Material examined. Lombok Island (Indonesia): 1 ♂ (holotype), Lombok Island, iv.1896, G. Breddin (DEI).

Acantholybas brunneus (Breddin)

Material examined. New South Wales: 1 ♀ (here designated lectotype), locality missing, date missing, G. Breddin; 1 ♂ (here designated paralectotype), New South Wales, date missing, G. Breddin (DEI). 1 ♂, Parramatta, near McCarthur's Bridge, among Gramineae, 29.iii.1980, R. Patterson (ANIC). New Zealand: 7 nymphs, 4 ♂♂, 15 ♀♀, Auckland, *Yuccoides beshorneria*, 1.iv.1993, D. Cowley (SBS).

Acantholybas kirkaldyi Bergroth

Material examined. Tasmania: 1 ♂ (here designated neotype), near Brooks Bay, *E. obliqua*, 7.ix.1993, M. Steinbauer; 1 ♀ (here designated paratype), "Copping" plantation near Nugent, *E. obliqua*, 2.xii.1994, M. Steinbauer (deposited in ANIC).

Amorbus spp. nymphs

Material examined. Australian Capital Territory: 1 V(♂), Black Mt, 15.iii.1964, Bancroft (DASUT); 1 V(♀), Pierces Creek, 25.i.1950, N. Newcombe (ANIC); . Western Australia: 3 IV, 1 V(♂), 1 V(♀), Walpole Coalmine Beach camping area, 27.i.1971, P.G. Kendrick; 1 IV, Ellenbrook, Glenbourne Farm, near Margaret River, 6.i.1978, P.G. Kendrick; 1 V(♂), Miling, xi.1974-ii.1975, A. Page; 1 IV, 2 V(♂♂), 1 V(♀), Augusta, 30.i.1963, P.Sundstrom; 6 IV, 1 V instar (sex unknown), 1 V(♂), 1 V(♀), Walpole, i.1968, G.W. Kendrick; 1 III, 2 IV, 2 V(♂♂), Kelmscott High School, 4.xii.1978, A. Page; 1 V(♂), Mundaring Weir, 6.ii.1963, J. Dell; 4 IV, 2 V(♂♂), 1 V(♀), Red Gum Spring, Stirling Range, on young suckers of *E. occidentalis*, 23.i.1970, P.G. + G.W. Kendrick; 1 III, 1 V instar (sex unknown), 1 V(♂), 1 V(♀), Mundaring Weir, 1.i.1963, J. Dell; 2 V(♀♀), Condingup, 26.i.1977, M.J. Douglas; 1 V(♂), Mundaring Weir, 16.i.1963, J. Dell; 1 V(♀), Mundaring Weir, 13.ii.1963, J. Dell; 1 III, 1 IV, Denmark, 20-30.i.1965, W.D.L. Ride; 1 V(♂), Kimberley Lennard River crossing, Gibb River Rd, 5.iv.1988, T.F. Houston; 1 V(♂), Eneabba, 8.iii.1989, R.P. McMillan (WAM); 2 V(♀♀), Darlington, Perth, *E. cinerea*, 20.i.1979, J. Neil; 3 V(♂♂), Mundaring, damaging *E. marginata* tips, 30.i.1963, D. Rimes (WADA). New South Wales:. 1 V(♀), Olney E.S.F., *E. pilularis*, 22.iii.1965, K.M. Moore; 1 V(♂), 2 V(♀♀), Olney E.S.F., *E. pilularis*, 16.iii.1965, K.M. Moore; 1 V(♂), Tumut, Bago S.F., 9.i.1991, C. Wilkinson; 1 V(♂), Bombala, Wog Station, *E. globulus*, 15.i.1991, W. Moore; 1 IV, 2 V(♂♂), Bombala, Wog Station, *E. globulus* 18 months, 8.i.1991, C. Stone; 1 V(♂), Bombala 'Ashdell' plantation, *E. nitens*, 1.iv.1992, J. Simpson C. Stone; 1 V(♀), Bombala 'Freitags' plantation, *E. globulus*, 1.iv.1992, J. Simpson C. Stone; 1 V(♂), 1 V(♀), Bombala 'Woolingubrah' plantation, *E. delegatensis*, 1.iv.1992, J. Simpson C. Stone; 1 V(♀), Pilliga, date missing, W.W.F.; 1 IV, 3 V(♂♂), 1 V(♀), Pilliga, 1925, W.W.F. (FCNSW); 1 V(♂), Albury, 6.i.1929, F.E. Wilson (MV). South Australia: 1 V(♂), 1 V(♀), Penola the 'Heath', *E. globulus*, ii.1990, B. Grigg (WAITE).

Amorbus affinis (Westwood)

Material examined. 1 ♂, 2 ♀♀, *Physomerus affinis* (syntypes), New Holland, date missing, Westwood (HEC).

Amorbus alternatus Dallas

Material examined. Queensland: 1 ♂, 1 ♀, Burrum River, 27.i.1975, B. Cantrell; 1 ♂, Taroom, xii.1930,

collector missing; 1 ♀, Indooroopilly, 15-22.xi.1979, collector missing; 1 ♀, Palmer River crossing, 30.i.1982, J.F. Donaldson; 1 ♀, Moores Creek, 10.xii.1932, collector missing; 1 ♀, Jindalee, 7.ii.1970, R.H.B.; 1 ♀, Moores Creek, 21.xi.1932, collector missing; 1 ♀, Indooroopilly, 5-12.xi.1982, collector missing (**DPIQ**); 3 ♂♂, 1 ♀, Lake Broadwater, 31.v.1984, M. Bennie; 1 ♂, Goodna, 10.xi.1924, H. Hacker; 1 ♂, Gatton, 2.xii.1933, M. Powell; 1 ♀, Brisbane, 23.ii.1925, H. Hacker; 1 ♀, Dalby, ii.1934, N. Gerry (**QM**); 1 ♀, Brisbane, 9.ix.1906, W.W. Froggatt; 1 ♀, Brisbane, xii.1981, Preston & Mafuar; 1 ♂, Bundaberg, on *Eucalyptus*, xii.1970, H. Frauca; 1 ♂, 1 ♀, Bundaberg, 9.ii.1971, H. Frauca (**ANIC**); 1 ♂, 1 ♀, Brisbane, date missing, Coates (**WADA**); 1 ♂, Ipswich, 20.v.1960, N. Heather; 1 ♂, Brisbane, 17.iv.1963,E.W. Brambleby; 1 ♂, 2 ♀♀, Pialba Rd, near Maryborough, on young *Eucalyptus*, xii.1959, R.A. O'Brien; 1 ♂, 1 ♀, Canungra Creek, 25.xii.1970, G.B. Monteith; 1 ♂, Kallangur, 24.iv.1967, E. Abbott; 3 ♂♂, 2 ♀♀, Mt Morgan, xi.1959, R.A. O'Brien; 1 ♂, St Lucia, 4.v.1966, R. Hunter; 1 ♀, Lake Moondarra, on *Eucalyptus* sp., 5.xi.1967, E.M. Exley; 1 ♂, Indooroopilly, 20.ii.1971, G.R.M. Grant; 1 ♂, Brisbane, 12.iv.1960, J. Martin; 1 ♀, Brisbane, 17.ix.1967, L.M. Cooper; 1 ♀, Brisbane, 5.ix.1965, M. Shelton; 1 ♀, Bald Mt, 3-4000', 16-20.ii.1970, G.B. Monteith; 1 ♀, Brisbane, date missing, R. Kumar; 1 ♂, St Lucia, 11.iv.1987, P. Surakrai; 1 ♀, Brisbane, 14.xi.1962, T. Brooks; 1 ♂, Quilpie, 11.iv.1971, G.B. Monteith; 1 ♀, Lawes, iv.1950, Lipsett; 1 ♂, Brisbane, 7.iv.1963, B. Ross; 1 ♂, Canungra, 31.i.1965, T. Weir; 1 ♀, Townsville, 16.viii.1957, D.M. Ellis; 1 ♀, Brisbane, 8.iv.1967, J. Abbott; 1 ♀, National Park, 25.x.1923, H. Hacker; 1 ♂, Brisbane, 15.xi.1938, collector missing; 1 ♂, Brisbane, 10.x.1937, B L. Bandidt; 1 ♂, Brisbane, 8.ix.1962, E. Craswell (**UQ**); 1 ♂, Mackay, date missing, collector missing; (**BCRI**). Western Australia: 2 ♀♀, Kimberley Lennard River crossing, Gibb River Rd, on *Eucalyptus* saplings, 5.iv.1988, T.F. Houston; 1 ♀, Kimberley Barker Gorge in Napier Range, 12.iv.1988, T.F. Houston; 1 ♀, Kimberley Windjana Gorge, 14.iv.1988, T F. Houston; 3 ♂♂, 4 ♀♀, Rawlinson Range, on *Eucalyptus* sapling shoots, 13-14.i.1990, T.F. Houston & M.S. Harvey (**WAM**); 1 ♀, Ivanhoe Station, vi.1944, C.F.A.J.; 1 ♀, Kimberley Research Station, 10.ii.1964, K.T. Richards (**WADA**). New South Wales: 3 ♂♂, 2 ♀♀, Cowra, 20-21.vii.1954, G.R. Wearne; 1 ♀, Deniliquin, 17.iv.1964, V.R. Squires; 1 ♀, Broken Hill, 19.xi.1949, S.J. Paramonov; 1 ♂, Albury, *E. blakelyi*, 5.xi.1961, K.L. Taylor; 1 ♂, Milparinka, 24.v.1949, K.H.L. Key; 1 ♀, Chinamans Dam, under *Eucalyptus* bark, 25.iv 1986, M.M. Stevens; 1 ♂, Fowlers Gap Research Station, 29.xi-2.xii 1981, I.D. Naumann; 1 ♀, Nyngan, 1-9.ii.1960, T.E. Woodward (**ANIC**); 2 ♀♀, Narromine, 4.xi.1903, W.W.F.; 1 ♂, 1 ♀, Wagga, 6.xi.1899, W.W.F.; 1 ♂, 2 ♀♀, Broken Hill, 10.iv 1944, C.E. Chadwick; 1 ♂, Hay, 1917, W.W.F.; 1 ♂, Hay, 1916, W.W.F.; 1 ♀, Broken Hill, 3.iii.1943, Chadwick (**BCRI**); 1 ♂, Deniliquin, 11.iii.1992, J. Heagney; 5 ♂♂, 1 ♀, Deniliquin, Gulpa Is S.F., 18-19.xi.1991, C.A.P. Urquhart & P. Hewat (**FCNSW**). Victoria: 1 ♀, Mooroopna, i-ii.1937, M.F. Day (**ANIC**). Northern Territory: 1 ♀, Todd River, 10.x.1978, M.S. Upton; 1 ♂, 1 ♀, Cadney Bore, 6.xii.1975, G. Griffin; 1 ♂, Entire Creek, 13.x.1978, M.S. Upton; 3 ♂♂, Alice Springs, 8.xi.1979, I.D. Naumann; 2 ♂♂, 1 ♀, Standley Chasm, 11.x.1972, M.S. Upton; 1 ♀, Standley Chasm, 5 x.1972, M.S. Upton (**ANIC**). South Australia: 1 ♀, Parachilna Gorge, 8.xi.1987, I. Naumann & J. Cardale; 2 ♂♂, 2 ♀♀, Parachilna Creek, 8.xi.1987, I. Naumann & J. Cardale; 2 ♂♂, 1 ♀, Wilpena Pound Gap, 5-6.xi.1987, I. Naumann & J. Cardale (**ANIC**); 1 ♂, Clare, under bark *Eucalyptus* sp., 25.xii.1967, C.E. Chadwick (**BCRI**); 1 ♂, 1 ♀, Riverland, on *Eucalyptus*, 1.ii.1977, collector missing; 1 ♂, Adelaide, on *Eucalyptus*, 10.xii.1963 (**NRLSA**), 1 ♀, Waite Agricultural Research Institute, on *Eucalyptus* sp., 5.i 1981, G.S. Taylor; 1 ♀, Royston Park, on citrus tree, ii.1978, M. Lvzeckyi (**WAITE**).

Amorbus angustior (Westwood)

Material examined. 1 ♂, *Physomerus angustior* (holotype), New Holland, date missing, Westwood (**HEC**).

Amorbus atomarius Stål

Material examined. Queensland: 1 ♀, Dunwich area, Stradbroke Island, 24-26.ix.1985, collector missing; 1 ♀, Indooroopilly, 10-20.i.1983, collector missing (**DPIQ**); 1 ♂, 2 ♀♀, Brisbane, 2.xii.1924, H. Hacker; 4 ♂♂, Brisbane, 3.xi.1924, H. Hacker (**QM**); 1 ♀, Cedar Creek, 2.iv.1964, R. Kumar; 1 ♂, Biggenden Bluff Range, 4.i.1972, H. Frauca; 1 ♂, Woowoonga Range, iii.1971, H. Frauca (**ANIC**); 1 ♀, Bald Mt, 3-4000', 22-27.i.1971, B.K. Cantrell; 1 ♀, Brisbane, 16.vi.1957, D. McColm; 1 ♂, Brisbane, 27.ix.1967, T. Lewis; 1 ♂, Brisbane, 15.iii.1966, B.F. Ingram; 1 ♀, Brisbane, 14.x.1962, T. Brooks; 1 ♀, Brisbane, date missing, R. Kumar; 1 ♂, Ashgrove, 10.viii.1965, D. Yule; 1 ♂, St Lucia, 11.iv.1987, P. Surakrai (**UQ**). Australian Capital Territory: 1 ♀, Black Mt, on *Eucalyptus*, iv.1963, T.G. Campbell; 1 ♂, Deakin, iv.1961, D.F. Waterhouse (**ANIC**). New South Wales: 1 ♂, Cassilis, 28.x.1966, T.G. Campbell; 1 ♀, Dangar's Falls, Armidale, 13.xii.1960, C.W. Frazier (**ANIC**); 5 ♂♂, 10 ♀♀, Tuena, 19.xi.1959, R.H. Muldez (**BCRI**).

Amorbus biguttatus Stål

Material examined. Queensland: 1 ♂, 1 ♀, Cardwell, date missing, K.B. (**QM**); 1 ♂, Palm Island, 20.xii-6.i.1930-1, I.M. Mackerras; 1 ♀, Fantome Island, v.1949, E. Revr (**ANIC**); 1 ♀, Mackay, ii.1964, J.E. Dunwoody (**UQ**).

Amorbus bispinus (Westwood)

Material examined. 1 ♂, 2 ♀♀, *Physomerus bispinus* (syntypes), Swan River, date missing, Westwood (**HEC**).

Western Australia: 2 ♂♂, 1 ♀, Denmark, 5-6.xi.1990, R.P. McMillan; 1 ♂, Mt Cooke, on flowers of *Eucalyptus*, 21.xi.1981, T.F. Houston; 1 ♀, Witchcliffe, on *Eucalyptus*, 14.xi.1986, T.F. Houston, 1 ♂, Walpole, i.1968, G.W. Kendrick; 1 ♂, Ellenbrook, 6.i.1978, P.G. Kendrick; 17 ♂♂, 17 ♀♀, Bickley, 18.x.1963, J. Dell; 1 ♀, Mundaring Weir, 1.i.1963, J. Dell; 1 ♂, Mundaring Weir, 26.ix.1962, J. Dell, 1 ♀, Darlington, 30.ix.1913, collector missing; 1 ♂, Noble Falls, on *Xanthorroea*, 24.xi.1958, R.P McMillan; 1 ♂, Mundaring Weir, 6.ii.1963, J. Dell; 1 ♀, Crawley, on Blackboy, 30.ix.1963, M.W. Fuller; 1 ♀, Mundaring Weir, 13.ii.1963, J. Dell (WAM), 1 ♂, 1 ♀, Blackwood River, 14.xi.1969, E. Britton; 1 ♂, Geraldton, 1913, Clarke; 1 ♂, Deep Dene, Karridale, 2.iv.1962, L.M. O'Halloran; 1 ♀, Albany, 5.x.1951, M.M. Wallace (ANIC); 3 ♂♂, Dwellingup, on *E. marginata* regrowth, 11.i.1972, S.J. Curry; 2 ♂♂, Bridgetown, x, L.J Newman; 3 ♂♂, 1 ♀, Kirup, on *E. marginata* suckers, 2.xi.1966, S.J. Curry; 2 ♀♀, Swan River, date missing, Lea; 1 ♂, Jarrahdale, date missing, collector missing (WADA); 1 ♀, Mandaring, in *E. marginata* forest, 30.x.1961, P.R.B. (NRLSA).

Amorbus obscuricornis (Westwood)

Material examined. 1 ♂, 1 ♀, *Physomerus obscuricornis* (syntypes), Van Diemens Land, date missing, Westwood (HEC); 1 ♂, locality missing, x.1910, Watsin; 1 ♂, Mt Wilson, 11.i.1929, Nicholson; 1 ♀, Pago Br, *E. dives*, 26.x.1971, K.O. H.M.; 1 ♂, Pago Bk, *E. dives*, 27.ii.1973, K.O. + A.M.; 1 ♀, Pago Bk, *E. dives*, 23.x.1972, K.O. + A.M.; 1 ♀, no details (ANIC); 1 ♂, locality missing, 15.xi.1911, C. French; 1 ♂, Sp. Vale, xi.1901, collector missing (MV); 2 ♂♂, 2 ♀♀, Mt Lofty summit, 22.xi.1947, D C.S. (WAITE)
Tasmania: 1 ♂, University, 16.x.1986, A. Baker; 1 ♂, Bushy Park, x.1974, M. Wells; 1 ♀, College Rd, x.1974, C.E. Young; 1 ♀, Hytten Hall, ix.1973, S.O.T. Yong; 1 ♀, Table Cape, xii.1973, M. Nazli; 2 II, 2 III, 2 IV, 25 ♂♂, 15 ♀♀, no details; 1 ♂, Kingston, 8.x.1990, N. Honeysett; 1 ♀, Richmond, 17.x.1981, I Stewart; 1 ♀, Mt Nelson, 26.x.1990, S. Archer; 1 ♂, Sandy Bay, 11.iii.1990, M. Mitchell; 1 ♂, Cremorne, xii.1963, G.C. Wade; 1 ♂, Knocklofty Reserve, 13.x.1993, B. Mounster; 1 ♂, Howrah, underneath *E. viminalis*, 6.x.1979, T. Groom; 1 ♂, Kingston, 30.ix.1990, A. Menary; 1 ♀, Boyer, 14.x.1993, P. Gore; 1 ♂, Mt Stuart, 15.viii.1992, A.J. Marshall; 1 ♀, Lenah Valley, 29.x.1992, C. Fyfe; 1 ♂, Orford, 12.ii.1983, J. Hughes; 1 ♂, Lower Sandy Bay, 14.viii.1991, R. Hickton; 1 V(♀), 2 ♂♂, Old Farm Rd, Hobart, 4.iv.1992, T. Hilbright; 1 ♀, Kingston, x.1976, P. Hofman; 1 ♂, Clifton, 29.xi.1978, L. Hulse; 1 ♀, Christ College, 22.x.1981, N. Roberts; 1 IV, Sandford, 11.i.1993, M.J. Jackson; 1 V(♀), Launceston Gorge, 25.ii.1992, C. Hogarth; 1 V(♂), Dromedary, iii.1993, D. MacCarrick; 2 ♂♂, Snug Plains, 8 iii.1979; J.L. Madden (DASUT); 3 ♂♂, 2 ♀♀, Wynyard, 6.i.1948, K.H.L. Key & P.B. Carne; 1 ♀, Burnie, 9.i 1948, K H L. Key & P.B. Carne, 1 V(♀), 1 ♀, Strahan, 28.i.1948, Key, Carne & Kerr; 1 ♂, Targa, 8.ii.1963, K L. Taylor, 1 V(♂), Geeveston, 31.i.1948, K.H.L. Key + P.B. Carne; 1 ♂, Mersey Valley, 23.i.1969, K.L. Taylor (ANIC); 1 ♀, Van Diemens Land, date missing, collector missing; 1 ♂, near Richmond, ii.1836, Burchell (HEC); 1 ♀, Launceston, date missing, Littler (BCRI); 1 ♀, Point Esperance, 28 iv.1913, C. French; 1 ♂, Hobart, 31.x.1915, C. Cole (MV); 1 nymph, Mt Nelson, *E. risdonii*, 10.xi.1969, collector missing; 3 nymphs, Coles Bay, *Eucalyptus* sp., 29.i.1967, collector missing; 1 nymph, New Norfolk, 28.i.1972, collector missing; 2 nymphs, 2 ♂♂, 3 ♀♀, Berriedale, on roses, 2.iii.1972, collector missing; 4 nymphs, Taroona, *Eucalyptus* sp., 15.i.1978, collector missing; 1 ♀, Lower Barrington, 29.xii.1990, collector missing; 1 ♂, 1 ♀, Hobart, date missing, Lea; 1 ♂, Grove, 10 xi.1971, collector missing; 1 ♂, 1 ♀, Mt Nelson, *Eucalyptus*, 6.i 1969, collector missing; 1 ♂, Apsley, *E. viminalis*, 13.xi.1974, collector missing; 1 ♂, Cambridge, *Eucalyptus*, 29.x.1975, collector missing; 1 ♂, 2 ♀♀, Bothwell, 27.x.1969, collector missing; 2 ♂♂, 2 ♀♀, Mt Nelson, *E. pulchella*, 5.x.1969, collector missing; 3 ♀♀, Cambridge, *Eucalyptus*, 28.x.1975, collector missing; 1 ♂, 4 ♀♀, New Norfolk, on raspberry bush, 28.i.1974, M.A. Stephenson; 1 ♀, Blackmans Bay, x.1940, collector missing; 1 ♂, New Norfolk, 6.x.1938, collector missing; 1 ♂, Cambridge, 25 iii.1974, collector missing; 1 ♂, Plenty, 11.xi.1975, collector missing; 1 ♂, 1 ♀, Lilydale, damaging *Eucalyptus* sp., 9.xii.1985, L. Hill; 1 ♀, Devonport, 31.iii.1992, L. Hill (TDPIF); 3 nymphs, St Helens, 26.xii.1962, B. Mollison (TM); 1 ♀, Black Bobs Rd, *E. ovata*, 14.i.1975, H. Elliott; 3 ♂♂, 1 ♀, Goulds, 1.xii.1988, H. Elliott; 1 ♂, Florentine Valley, *E. regnans*, 23.x.1974, H. Elliott; 2 ♂♂, 2 ♀♀, Goulds, 28.x.1988, H. Elliott; 2 ♀♀, Branchs Creek, *E. viminalis*, 14.i.1975, H. Elliott; 1 ♂, Lake Leake, *E. dalrympleana*, 12.xi.1977, H. Elliott; 1 ♂, Lake Leake, *E. delegatensis*, 16.iii.1982, H. Elliott; 1 ♂, Bicheno, *E. amygdalina*, 18.x.1978, H. Elliott; 1 ♂, Lake Leake, *E. amygdalina*, 17.xi.1977, H. Elliott; 1 ♂, Woodsdale, *E. amygdalina*, 10.xi.1977, H. Elliott; nymphs, adults, Woodsdale, *Eucalyptus*, 1992, R. Bashford; nymphs, adults, Forester, Scottsdale, *Eucalyptus*, 1992, R. Bashford; nymphs, Arm River, Mersey, *Eucalyptus*, 1992, R. Bashford; nymphs, adults, Smiths Plains, Devonport, *Eucalyptus*, 1992, R. Bashford; nymphs, adults, Geeveston, *Eucalyptus*, 1992, R. Bashford; nymphs, Sidling, Scottsdale, *Eucalyptus*, 1992, R. Bashford (FT); 1 ♂, Maggs Mt, 17.ii.1975, R.H. Green; 3 V(♀♀), Maggs Mt, *Eucalyptus*, 25.iii.1975, R.H. Green; 1 ♀, Maggs Mt, 11.iv.1988, R.H. Green; 2 ♂♂, Maggs Mt, *Eucalyptus*, 7.iv.1989, R.H. Green; 4 ♂♂, 7 ♀♀, Maggs Mt, *Eucalyptus*, 450 m, 2.xi.1988, R.H. Green; 2 V(♀♀), Maggs Mt, 29.iv.1975, R.H. Green; 1 ♂, 2 ♀♀, Maggs Mt, *Eucalyptus*, 15.xii.1976, R.H. Green; 6 III, 9 IV, 2 V(♂♂), 1 V(♀), 1 ♂, 1 ♀, Maggs Mt, *Eucalyptus*, 23.ii.1989, R.H. Green; 2 II, 6 III, 1 IV, 2 ♂♂, 1 ♀, Maggs Mt, *Eucalyptus*, 13.i.1976, R.H. Green; 1 ♂, 3 ♀♀, Maggs Mt, *Eucalyptus*, 20.i.1977, R.H. Green; 4 II, 25 III, 28 IV, 6 V(♂♂), 5 V(♀♀), 1 ♂, Maggs Mt, *Eucalyptus*, 25.ii.1986, R.H. Green; 5 ♂♂, 2 ♀♀, Maggs Mt, 11.xi.1975, R.H. Green (QVM). New South Wales: 1 ♂, 1 ♀, above Junction Shaft, Snowy Mts, 4800', 23.xi.1956, I.G. Filmer (QM); 1 ♂, Dainers Gap, 1585 m, ex *E. perriniana*, 6.iii.1974, P.

Morrow; 1 ♂, Shoalhaven, 9.xi.1894, Froggatt; 1 ♂, 1 ♀, Leather Barrel Creek, *E. pauciflora* and *E. dalrympleana*, 31.x.1961, K.L. Taylor; 1 ♂, 2 ♀♀, The Creel, Thredbo River, *E. pauciflora*, 30.x.1961, K.L. Taylor; 2 ♂♂, 3 ♀♀, Pilot Hill, *E. delegatensis*, 12.ii.1981, C.P. Ohmart; 1 ♂, Pilot Hill, *E. delegatensis*, 13.x.1981, C.P. Ohmart; 1 ♂, New England National Park near entrance, 22.xi.1959, C.W. Frazier (**ANIC**); 1 ♀, Gibraltar Range, 3000', 27-19.xii.1972, G.B. Monteith; 1 ♀, Poverty Point, 3000', 21-22.x.1973, G.B. Monteith (**UQ**); 1 ♂, Leura, 4.i.1903, W.W. Froggatt; 1 ♀, Wulcha, 20.ii.1905, W.W. Froggatt; 1 ♀, Schum, 20.x.1904, W.W. Froggatt; 1 ♂, Hampton, on *Angophora* sp., 27.xii.1968, C.E. Chadwick; 1 ♂, 1 ♀, Jenolan State Forest, on *Eucalyptus* sp., 29.xii.1968, C.E. Chadwick; 1 ♀, Albury, 22.iii.1906, W.W. Froggatt; 1 ♂, Juno River, 1904, W.W. Froggatt; 1 ♀, Dawsons Spring, 1420 m, G.R. Brown; 2 ♂♂, 5 ♀♀, Island Bend, Mt Kosciusko, 24.xi.1952, C.E. Chadwick; 3 ♂♂, 2 ♀♀, Island Bend, Mt Kosciusko, *E. delegatensis*, 22.i.1957, C.E. Chadwick; 1 ♀, Island Bend, Mt Kosciusko, *E. dalrympleana*, 23.i.1957, C.E. Chadwick; 1 ♂, 2 ♀♀, Island Bend, Mt Kosciusko, *E. dalrympleana*, 18.i.1957, C.E. Chadwick; 3 ♂♂, 3 ♀♀, Island Bend, Mt Kosciusko, on *Eucalyptus*, 24.xi.1952, C.E. Chadwick; 1 ♂, 1 ♀, Island Bend, Mt Kosciusko, on *Eucalyptus* sp., 17.xii.1953, C.E. Chadwick (**BCRI**); 2 ♂♂, Tumut, Bago State Forest, 9.i.1991, C. Wilkinson; 2 ♂♂, Nundle State Forest, *E. stellulata*, 19.xi.1962, K.G. Campbell; 1 ♂, Bago State Forest, 13.iii.1953, K.M. Moore; 1 ♀, Nundle State Forest, *E. viminalis*, 19.xi.1962, K.G. Campbell; 3 ♀♀, Bombala 'Ashdell' plantation, *E. fastigata*, 1.iv.1992, C. Stone (**FCNSW**); 1 ♂, 1 ♀, New South Wales, date missing, collector missing (**MV**). Australian Capital Territory: 1 ♀, Mt Aggie, 1380 m, 11.xii.1973, N.B. Tindale (**SAM**); 1 ♀, Canberra, 8.xi.1929, G.A. Waterhouse; 1 ♂, Mt Gingera, 5700', 29.i.1961, P.B. Carne; 1 ♀, Mt Gingera, 13.iii.1951, P.B. Carne; 1 ♀, Mt Gingera, 5.xii.1950, H.M. Cane; 1 ♂, Canberra, xi.1929, J.W. Evans; 1 ♀, Black Mt, on *E. rossi*, 15.ii.1971, H.J.E.; 1 ♂, 1 ♀, Black Mt, *E. maculata*, 30.xi.1971, H.M. + A.M.; 1 ♂, 1 ♀, Black Mt, *E. macrorrhyncha*, 2.xii.1971, H.M. K.D.; 1 ♂, 1 ♀, Bulls, *E. pauciflora*, 14.xii.1971, H.M. K.O.; 1 ♂, Bulls H, *E. pauciflora*, 21.iii.1972, K.O. + A.A.; 1 ♂, 1 ♀, Bulls Hd, *E. pauciflora*, 23.x.1972, K.O. + A.M., 1 ♂, Bulls, *E. pauciflora*, 8.ii.1972, H.M. K.O.; 1 ♂, Bulls, *E. pauciflora*, 7 xii.1971, H M. K.O.; 1 ♂, Bulls Hd, *E. pauciflora*, 3.x.1972, K.O. + A.M.; 2 ♂♂, 1 ♀, Bulls Hd, *E. pauciflora*, 30 i.1973, P.H. + J.B.; 1 ♂, Bulls Hd, *E. dalrympleana*, 17.x.1972, K.D. + A.M.; 1 ♂, Bulls, *E. dalrympleana*, 14.xii.1971, H.M. K.O.; 1 ♀, Bulls Hd, *E. dalrympleana*, 3.x.1972, K.O. + A.M., 1 ♂, Bulls, *E. dalrympleana*, 15.iii.1972, H.M. K.O.; 1 ♀, Bulls Hd, *E. dalrympleana*, 20.ii.1973, K.O. + A.M.; 1 ♂, Bulls Hd, *E. dalrympleana*, 23.i.1973, K.O. + P H.; 3 ♂♂, 1 ♀, Mt Franklin, 8.ii.1984, A. Calder & M. Stevens (**ANIC**); 1 ♂, Queanbeyan, i.1892, Lea (**BCRI**); 1 ♀, Mt Franklin, *E. pauciflora*, 10.i.1968, B.C.P.; 1 ♀, Mt Ginini, *E. pauciflora*, 10.i.1968, B.C.P (**WAITE**). South Australia: 1 ♂, Bridgewater, 17.x.1947, F.M. Angel (**SAM**); 1 ♀, Lenswood, on *Bursaria spinosa*, 10.i.1980, G J Baker (**NRLSA**); 1 ♀, Penola, the 'Heath', *E. globulus*, ii 1990, B. Grigg (**WAITE**). Queensland: 1 ♂, Brisbane, 18.ii.1964, R. Kumar; 1 ♂, Bolton's Ridge, *E. pauciflora*, 20.xii.1972, collector missing (**ANIC**); 2 ♀♀, Brisbane, date missing, R. Kumar; 1 ♀, Bald Mt, 3-4000', 27-31.i.1972, G.B. Monteith (**UQ**). Victoria: 1 ♂, Cobungra, 30.iii.1967, K.H.L. Key; 1 ♂, Traralgon, ii.1960, R.A. Beeching (**ANIC**); 1 ♀, Wilsons Promontory, 25.xii.1905, J.A.K.; 1 ♀, Warburton, 11.iii.1922, collector missing (**MV**).

Amorbus rhombeus (Westwood)

Material examined. 1 ♂, *Physomerus rhombeus* (holotype), Melville Island, date missing, Westwood (**HEC**).

Amorbus rhombifer (Westwood)

Material examined. 1 ♂, *Physomerus rhombifer* (holotype), locality missing, date missing, Westwood (**HEC**); 2 ♂♂, no details (**QM**); 1 ♂, Running Creek, 15.iv.1941, A.W. Smith; 1 ♂, no details; 1 ♂, 1 ♀, Glasshouse, 29.x.1941, A.R.B.; 1 ♀, Mackay Kuttabul, 8.xii.1932, W.A. McDougall (**DPIQ**); 1 ♀, W.W. Froggatt collection (**ANIC**); 1 ♀, locality missing, 4.xi.1922, Allman (**BCRI**). Papua New Guinea: 1 ♀, Paga Hill, Port Moresby, 26.i.1966, E. Mann (**UQ**). Queensland: 1 ♂, Moreton Tel. Stn., Cape York Peninsula, 30.vi.1975, G.B. Monteith; 1 ♂, Andoom, near Weipa, 5-8.ii 1975, G.B. Monteith; 1 ♂, Blackdown Tableland, 1-6.ii 1981, G.B. Monteith; 1 ♀, Sundown National Park, 5-8.iv.1985, G.B. Monteith; 1 ♀, Kroombit Tops, 1000-1100 m, 22-26.ii.1982, Monteith, Thompson & Yeates; 1 ♂, Stradbroke Island, 2.x.1911, H. Hacker; 1 ♂, Camp Milo, Cooloola, 15-18.x.1978, G.B. Monteith; 1 ♀, Curtis Farm, 30.i-1.ii.1982, G.B. Monteith; 1 ♂, Mt Cleveland summit, 13.i.1991, A. Graham; 1 ♀, Mt Elliot, 200-800 m, 25-27.iii.1991, G. Monteith & D. Cook; 1 ♂, Brisbane, 23.x.1911, H. Hacker; 1 ♀, Brisbane, 9.iii.1925, H. Hacker; 1 ♂, Cairns, date missing, J.F. Illingworth; 1 ♂, Brisbane, 16.x.1911, H. Hacker (**QM**); 1 ♀, Brisbane, 16.v.1921, H. Jarvis (**DPIQ**); 1 ♀, Brock Creek, Burnside, 28.iii.1929, T.G. Campbell; 1 ♂, 1 ♀, Cairns, 20.iv.1905, Hucker; 1 ♂, Palm Island, 20.xii-6.i.1930-1931, I.M. Mackerras; 1 ♂, Bowen, 26.ix.1950, E.F. Riek; 2 ♂♂, Biggenden, 9.i.1971, H. Frauca; 1 ♀, Banks Island, 1910, Elzner; 1 ♂, southern Queensland, 24.iv.1964, R. Kumar; 1 ♂, 1 ♀, Bluff Range, 18-19.xii.1971, H. Frauca; 1 ♂, Bluff Range, 16.xii.1971, H. Frauca; 1 ♂, Woowoonga Range, *Eucalyptus*, iii.1971, H. Frauca; 1 ♂, 1 ♀, Biggenden, 9.i.1973, H. Frauca; 1 ♂, 1 ♀, Bundaberg, iii.1971, H. Frauca; 1 ♂, 1 ♀, Annan River, 27.ix.1980, T. Weir; 1 ♂, Watalgan Range, dry sclerophyll, 1500', 23.x.1971, H. Frauca; 1 ♂, Bluff Range, 17.xii.1971, H. Frauca; 1 ♀, Bluff Range, 10.i.1972, H. Frauca; 1 ♂, Biggenden Bluff Range, 19-20.xii.1972, H Frauca; 1 ♂, 2 ♀♀, Woowoonga Range, 2000', ii.1971, H. Frauca; 1 ♀, Biggenden Bluff Range, 3.i.1973, H. Frauca; 1 ♀, Biggenden Bluff Range, 9.i.1971, H. Frauca; 1 ♀, Bundaberg, 9.ii.1971, H. Frauca (**ANIC**); 4 ♂♂, 2 ♀♀,

Brisbane, date missing, R. Kumar; 1 ♂, Brisbane, 12.xii.1962, M. Tapiolas; 1 ♀, Stradbroke Island, Dunwich, 21.iii.1970, collector missing; 1 ♀, Brisbane, 31.vi.1954, A.G Barrie; 1 ♂, Brisbane, 13.iii.1971, A.L. Bishop; 1 ♂, Brisbane, 7.xii.1961, B.F. Stone; 1 ♂, Oxley, Brisbane, 4.i.1971, K. Houston; 1 ♂, Iron Range, Cape York Peninsula, 28.iv-4.v 1968, G. Monteith; 1 ♂, Iron Range, Cape York Peninsula, 5-10.v.1968, G. Monteith; 1 ♀, Iron Range, Cape York Peninsula, 1-9.vi.1971, G.B. Monteith; 1 ♂, Yeppoon, 14.iv.1935, collector missing; 1 ♂, Brisbane, 7 vii.1971, D. Murray; 1 ♀, Lawes, iv.1954, A.J. Cowan; 1 ♀, Ormiston, viii.1954, J.K. Leslie; 1 ♀, Iron Range, Cape York Peninsula, 26-31.v.1971, G.B. Monteith; 1 ♀, Brisbane, 13.xii.1965, E.B. Tay; 1 ♀, Brisbane, 30.iv 1956, I. Bonner; 1 ♀, Stradbroke Island, Dunwich, 17.iv.1963, G. Monteith; 1 ♀, Noosa National Park, 13.xii.1965, G. Monteith; 1 ♀, Jondaryan, 13.iv.1963, C. Speed; 1 ♀, Brisbane, iv.1964, J.E Dunwoody; 1 ♀, Yengarie Rd Maryborough, on young *Eucalyptus*, xi.1959, R.A. O'Brien; 1 ♀, Brewers Cl., 15.i.1933, collector missing (UQ). New South Wales: 1 ♂, Dee Why, ii.1928, M. Fuller; 1 ♂, Narrabeen, 15.ix.1934, D.F.W.; 1 ♂, Como, 27.x.1893, Froggatt; 1 ♀, Point Perpendicular, Jervis Bay, 30.xii.1966, K.H.L. Key (ANIC); 1 ♀, Bardwell, 2.ii.1941, collector missing; 1 ♀, Bardwell Park, 20.i.1941, collector missing; 8 ♂♂, 6 ♀♀, Cobbitty, on *Angophora subvelutina*, 6.iii.1960, C.E. Chadwick; 1 ♀, Bouddi National Park, 5.ii.1967, collector missing; 1 ♂, near Mitchells lookout, 28.ix.1958, W.E. Wright; 1 ♀, Helensburgh, iii 1962, H.E. Osburne; 1 ♂, Moffatt Beach, 2-15.iii.1970, O.M. Williams; 1 ♂, Helensburgh, ix.1961, H E. Osburne; 1 ♂, Cobbitty, attacking *E. amplifolia*, 6.iii.1960, C.E. Chadwick; 1 ♀, Graman, on lucerne, 10.xi.1960, P.G. Pegan; 1 ♀, Kurnell, attacked by asilid fly, 6.xii.1969, C.E. Chadwick (BCRI). Western Australia: 1 ♀, Kununurra, 28.ii.1960, K.T. Richards (WADA). Victoria: 1 ♂, Lake Hattah, date missing, J.E. Dixon (MV).

Amorbus robustus Mayr

Material examined. 1 ♀, *A. robustus* (holotype), Sydney, date missing, Mayr (NMW); 2 ♂♂, 2 ♀♀, no details (DPIQ). Papua New Guinea: 1 ♂, 1 ♀, Port Moresby, 1 ii.1956, J.H. Barrett (UQ). Queensland: 1 ♂, Wacol, 9 iii.1970, R.H. Broadley; 1 ♂, 1 ♀, Gin Gin, on ironbark trees (*Eucalyptus* series Siderophloiae), 17.ii.1992, J. Wright; 1 ♂, 2 ♀♀, Baracula, *Eucalyptus crebra*, 12.x.1938, A.R.B.; 1 ♀, Toowoomba, 10.i.1964, J.W. Turner; 1 ♀, Clermont, 1938, A.R.B (DPIQ); 1 ♂, 1 ♀, Blackdown Tableland, 1-6.ii.1981, G.B. Monteith; 1 ♀, Mt Finnigan, 850-1100 m, 19-22.iv.1982, Monteith, Yeates & Cook; 1 ♀, Cedar Creek, 17.iii.1958, M. Fearnley; 1 ♀, Undara Lava Tunnels, 5.ix.1989, collector missing; 2 ♂♂, 1 ♀, Dalby, ii.1934, N. Geary; 1 ♀, Dalby, xii.1933, N. Geary; 1 ♂, Portland Rd, Cape York Peninsula, 31.v.1948, D.P. Vernon; 1 ♂, Indooroopilly, 20.iv.1930, A.A. Girault; 1 ♂, Brisbane, 25.ii.1952, D.P. Vernon; 1 ♂, 2 ♀♀, Brisbane, 23.ii.1925, H. Hacker; 1 ♀, Brisbane, 30.x.1911, H. Hacker; 1 ♂, Brisbane, 23 x.1911, H. Hacker (QM); 1 ♀, Mackay, 28.iii.1962, Chinnick & Corby; 1 ♂, Brisbane, 3.xii.1906, collector missing; 1 ♂, Biggenden Bluff Range, 1-7.i.1972, H. Frauca, 1 ♀, Brisbane, 14.x.1906, collector missing; 1 ♂, 1 ♀, Cairns, 1905, Hucker; 1 ♀, Brisbane, date missing, collector missing; 1 ♀, Thursday Island, *Eucalyptus*, 5.xii.1976, Paton; 1 ♂, Watalgan Range, dry sclerophyll, 1500', 23 x.1971, H. Frauca; 1 ♀, Marmor, 13.xii.1968, Britton & Misko; 2 ♂♂, banks of Burnett River, on *Eucalyptus*, iii.1971, H Frauca; 2 ♂♂, 3 ♀♀, Almaden, 500 m, 31.iii.1984, A. Calder & T. Weir; 1 ♀, Bundaberg, ii.1971, H. Frauca; 1 ♀, Mt Walsh National Park, 1-2.i.1972, H. Frauca (ANIC); 1 ♀, Brisbane, 4.iv.1951, B. Champ; 1 ♂, St Lucia, *Eucalyptus*, 16.v.1987, P. Surakrai, 1 ♂, Brisbane, iv.1957, N. McKenna; 1 ♂, Brisbane, 4.iii.1956, S. Sekon; 1 ♂, Brisbane, 10.x.1962, G. Monteith; 3 ♂♂, Beames Brook, 20.v.1972, G B. & S.R. Monteith; 1 ♂, Mackay, 30 xi.1963, P. Kerridge; 1 ♂, Brisbane, 2.i.1963, G. Monteith; 1 ♂, Brisbane, iv.1937, D.B. Jones; 1 ♀, Iron Range, Cape York Peninsula, 1-9.vi.1971, G.B. Monteith; 1 ♂, McIvor River, 7.v.1970, G.B. Monteith; 1 ♂, 1 ♀, Maryborough, Granville, on young *Eucalyptus*, xi.1959, R.A. O'Brien; 1 ♀, Mt Carbine, 5.i.1964, G. Monteith; 1 ♀, Brisbane, 26.iii.1966, B.F. Ingram; 1 ♀, Windorah, 9.iv.1971, G.B. Monteith; 1 ♂, Brisbane, 17.i.1971, L. Hill; 1 ♂, Sandgate, 8.iii.1955, D. Griffith; 1 ♂, Brisbane, date missing, A. Rosser, 1 ♂, Moggill, Brisbane, on *Eucalyptus*, 15.v.1958, T.E. Woodward; 1 ♂, Brisbane, 15.ix.1966, E. Rainey; 1 ♂, Brisbane, 3.iv.1966, F.R. Wylie; 1 ♂, North Pine Rd, 4.xii.1962, G. Monteith (UQ); 1 ♂, Gatton, 1.iv.1905, E.H.G.; 1 ♂, Torrens Creek, viii.1976, collector missing; 1 ♀, Mackay, ii.1899, collector missing; 1 ♂, near Charters Towers, 25.iii.1902, Black (BCRI); 1 ♂, Cunnamulla-Eulo, on coolibah, 15.iii.1964, P.R.B (NRLSA). New South Wales: 1 ♀, Pilliga, 1928, W.W. Froggatt (ANIC); 1 ♀, Tamworth, 5.i.1981, C. Easton; 1 ♀, Dubbo, on young *Eucalyptus* ornamentals wilting growing tips, 5.xii.1977, J. Kneipp; 1 ♀, near Tweed River, 23.xi 1903, W.W. Froggatt; 1 ♂, Graman, feeding on *E. albens*, 19.i.1959, T.V. Bourke; 1 ♂, Warrumbungle National Park, 23.iv.1967, C.E. Chadwick; 1 ♂, Tamworth, 9.x.1892, Lea; 1 ♀, Narrandera, on young *Eucalyptus* sp., 15.i.1963, P. Wong (BCRI); 2 ♀♀, Narrandera, on *E. melliodora*, 26.x.1963, T.P. O'Rourke (FCNSW). Northern Territory: 1 ♂, Auvergne homestead, 28.v.1968, M. Mendum; 1 ♂, McArthur River, 29.x.1975, M.S. Upton; 1 ♀, Alice Springs, 8.xi.1979, T. Weir; 1 ♂, Illungnarra waterhole, 15.x.1978, M.S. Upton (ANIC). Western Australia: 1 ♂, Kalumburu mission, 7-11.vi.1988, T. Weir; 1 ♂, Broome, 11.viii.1976, I.F.B. Common (ANIC); 1 ♂, Wyndham, date missing, L.J. Newman; 1 ♀, Dillon Spring, Kwnuwurra, 19.xii.1968, D.G. Snedley (WADA); 1 ♀, Wyndham, ii.1954, K.R.S. (QM).

Amorbus rubicundus Stål

Material examined. 1 ♀, *Amorbus rubicundus* (allotype), Sydney, date missing, Stål (SAM).

Amorbus rubiginosus (Guérin-Méneville)

Material examined. 1 ♂, *Coreus rubiginosus*, locality missing, date missing, possibly from Guérin-Méneville's collection (I. Lansbury *in lit.*); 1 ♂, New Holland, date missing, collector missing **(HEC)**; 3 ♂♂, 3 ♀♀, no details; 1 ♂, Glasshouse Mt, 10.xi.1937, A.R.B.; 1 ♂, 1 ♀, Rosedale, 1935, L.G. Dovey **(DPIQ)**; 3 ♂♂, 2 ♀♀, no details; 2 ♂♂, North Bridge, 27.x.1927, collector missing; 1 ♂, Gundamain, 1.x.1928, M. Fuller **(ANIC)**; 1 ♂, Forest, date missing, Berfs; 1 ♀, no details; 1 ♂, Newholme, 26.ix.1980, A.J. Campbell **(BCRI)**; 1 ♂, Clare, *E. leucoxylon*, 25.xii.1963, P.R.B.; 1 ♀, Mt Beauti, 26.i.1967, N.T.M. **(NRLSA)**. New South Wales: 1 ♂, Charlestown, *Eucalyptus* coppice, 15.i.1936, collector missing **(DPIQ)**; 2 ♂♂, Pilliga, 1925, W.W. Froggatt; 1 ♂, Armidale, 1926, W.W. Froggatt; 2 ♂♂, 3 ♀♀, Albury, *E. blakelyi*, 5.xi.1961, K.L. Taylor; 1 ♂, Wallambine Creek, under logs, 29.xi.1967, Britton & Misko; 1 ♂, 1 ♀, Tumblong, near Gundagai, 21.ii.1951, Key & Chinnick; 1 ♂, Shoalhaven, 1895, G.W.F.; 1 ♀, locality missing, 1913, collector missing; 2 ♂♂, Conjola, 15.x.1966, I.F.B. Common & M.S. Upton; 1 ♀, Adelong, 20.ii.1951, Key & Chinnick; 1 ♂, Nerriga, 22.xi.1950, K.H.L. Key; 1 ♂, Roseville, 26.xii.1922, M. Fuller; 2 ♂♂, 1 ♀, Kiandra, 31.i.1964, T.G. Campbell; 1 ♂, Young, 23 xi.1950, N. Newcombe; 1 ♀, Shoalhaven, 9.x.1894, collector missing; 1 ♀, Yass, 20.xii.1925, K. English; 1 ♂, 1 ♀ (*in copula*), 33.42S 151.16E, feeding on young shoots of *Angophora hispida*, 3.x.1981, C.A. Henley; 1 ♀, Armidale, 30.i.1970, R.J. Roberts; 1 ♂, New England University, Armidale, 24.xi.1971, 24.xi.1971, C.W. Frazier; 3 ♀♀, Tea Tree Creek, 15.xi.1959, C.W. Frazier; 1 ♂, 1 ♀, Chandler River, 16.iii.1966, C.W. Frazier; 1 ♂, Chandler River, 28.iii.1966, C.W. Frazier; 3 ♀♀, Stony Creek Falls, 18.xii.1968, Britton & Misko **(ANIC)**; 1 ♂, Sydney, date missing, Lea **(WADA)**; 2 ♂♂, 3 ♀♀, Pilliga Scrub, 19-20.x.1973, G.B. Monteith; 1 ♂, 1 ♀, Sydney, date missing, Deane; 1 ♂, Nyngan district, 1-9.ii.1960, T.E. Woodward **(UQ)**; 1 ♂, 1 ♀, Albury, iii.1905, W.W. Froggatt; 1 ♂, Kuringgai Chase, 10.xii.1961, C.E. Chadwick; 1 ♀, Engadine, *Angophora hispida*, 15.xii.1957, C.E. Chadwick; 1 ♂, 1 ♀, Menai, 1 iv.1962, C.E. Chadwick; 1 ♂, Lowther, *E. dives*, 29.xii 1968, C.E. Chadwick; 1 ♂, Mittagong, *Eucalyptus*, 11.xi.1962, A.H.; 1 ♂, Wagga, ix, J. Kell; 1 ♂, 2 ♀♀, Mt Colah, sucking sap of young leaves of *Angophora* sp., C.E. Chadwick; 2 ♀♀ (identity of one uncertain), Mittagong, 26.xi.1901, W.W. Froggatt; 1 ♂, Albury, 23.x.1967, R.J. Flynn; 1 ♂, 1 ♀, Newnes, *Eucalyptus*, 25 i.1969, C.E. Chadwick; 1 ♂, Hornsby, 15.iii.1961, collector missing, 1 ♀, Penrose, 23.xii.1909, collector missing; 2 ♀♀, Cabramatta, 25.x.1959, C.E. Chadwick; 1 ♀, Bibbenluke, 23 ii.1961, T.V. Bourke; 1 ♀, Wulcha, 20.ii.1905, W.W. Froggatt; 1 ♂, Frenchs Forest, *Angophora hispida*, 20.xi.1960, C.E. Chadwick, 1 ♀, Bathurst, 1.xii.1925, S.L.A.; 1 ♂, 2 ♀♀, Blowering Dam, 7.i.1972, C.E. Chadwick; 1 ♂, 1 ♀, Lindfield, 16.x.1966, D.A. Doolan; 1 ♂, 1 ♀, Coonabarabran, attacking young shoots of *E. globulus* subsp. *bicostata*, 18.ii.1963, C.E. Chadwick; 1 ♀, East Killara, *Angophora hispida*, 16.xii.1962, C.E. Chadwick, 1 ♂, 1 ♀, Gosford district, *Angophora*, 6.xii.1949, P.C. Hely; 1 ♂, Heathcote, 28.xi.1964, D.A. Doolan; 1 ♂, Bardwell Park, 20.i.1941, collector missing; 2 ♀♀, Goulburn, young *E. globulus* subsp. *globulus*, 2.xii.1982, J. Hallam; 1 ♀, locality missing, 12.xi.1904, collector missing; 1 ♂, Gosford district, on beans, 17.xi.1949, P.C. Hely **(BCRI)**; 1 ♀, Bathurst, Macquarie Woods, *E. sideroxylon*, 17.i.1991, C. Urquhart, D. Hopham; 1 ♂, Bathurst, Macquarie Woods, *E. melliodora*, 17.i.1991, C. Urquhart, D. Hopham; 1 ♂, Pilliga, 1928, collector missing; 1 ♂, Olney, *E. pilularis*, 16.iii.1965, K.M. Moore; 1 ♂, 1 ♀, Olney State Forest, *E. pilularis*, 31.iii 1965, K.M. Moore; 3 ♂♂, 3 ♀♀, Bathurst, Macquarie Woods, 5 xii.1990, J. Fulton; 1 ♂, 2 ♀♀, Bombala Wog Station, *E. globulus* 18 months, 8.i.1991, C. Stone; 2 ♂♂, 1 ♀, Bombala Wog Station, *E. globulus*, 15.ii.1991, W. Moore; 1 ♀, Bombala, 'Freitags' plantation, *E. globulus*, 1.iv.1991, C. Stone **(FCNSW)**; 1 ♂, Wardell, i.1933, J. Clark **(MV)**. Queensland: 1 ♀, Brisbane, date missing, T. Batchelor; 1 ♀, Brisbane, date missing, H. Tryon; 1 ♂, Atherton, 21.iv.1941, A.R.B.; 1 ♂, Childers, 4.ii.1992, J. Sullivan; 1 ♂, Thursday Island, 29.i.1986, E.L. Hamacek; 1 ♂, Stanthorpe, 8 xi.1928, H. Jarvis; 1 ♀, Stanthorpe, damaging foliage of apple, xi.1919, H. Jarvis; 1 ♂, 2 ♀♀, Brisbane, 8.iii.1971, R.H. Broadley **(DPIQ)**; 1 ♀, Wylie Creek, legume, 29.i.1962, J. Bancroft; **(DASUT)**; 1 ♀, Blackdown Tableland, 1-6.ii.1981, G.B. Monteith; 1 ♀, Mt Blackwood, 10.vi.1971, E.C. Dahms; 1 ♀, Brisbane, 22.x.1917, H. Hacker; 1 ♀, Acacia Ridge, 19.ii.1969, E.C. Dahms; 2 ♂♂, 6 ♀♀, Mt Elliot, 200-800 m, 25-27.iii.1991, G. Monteith & D. Cook; 1 ♀, Mt Cleveland, 200-400 m, 22.iii.1991, G. Monteith & D. Cook; 4 ♂♂, 4 ♀♀, Brisbane, 23.ii.1925, H. Hacker; 1 ♂, Brisbane, 22.x.1917, H. Hacker; 1 ♂, Brisbane, 22.xii.1917, H. Hacker; 1 ♀, Brisbane, 30 iii.1925, H. Hacker; 1 ♀, Brisbane, 30.x.1911, H. Hacker; 1 ♂, Stanthorpe, 2-4.xi.1914, collector missing; 1 ♂, locality missing, xi.1993, collector missing; 2 ♀♀, Blencoe Creek Gorge, 20.v.1960, C. Calder **(QM)**; 1 ♂, Oxley, 13.i.1974, G.F. Gross **(SAM)**; 1 ♂, Brisbane, 25.xii.1906, collector missing; 1 ♀, Springcliff area near Mackay, 28.i.1965, J.E. Dunwoody; 2 ♂♂, "Coonardoo", Fletcher, 4.xii.1966, T.G. Campbell; 2 ♀♀, Fletcher, 16.xii.1966, E. Sutton; 2 ♂♂, 3 ♀♀, Fletcher, i.1967, E. Sutton; 1 ♂, Brisbane, 18.ii.1964, R. Kumar; 4 ♂♂, 7 ♀♀, Gumdale, on young *Eucalyptus* sp., 24.i.1967, J.K. Guyomar; 1 ♀, banks of Burnett River, *Eucalyptus*, iii.1971, H. Frauca; 1 ♂, Brisbane, 29.iii.1906, collector missing; 1 ♂, Brisbane, 14.x.1906, collector missing; 1 ♀, Brisbane, 26.xii.1906, collector missing; 1 ♀, Cordalba State Forest, 1.v.1979, collector missing **(ANIC)**; 1 ♀, Brisbane, 2.iv.1959, M. Hamon; 1 ♂ (identity uncertain), Brisbane, 24.xi.1963, B.V. Timms; 1 ♀, Beaudesert, 1.v.1955, R.E. Harrison; 1 ♂, Stanthorpe, 20.i.1965, B. Alcock; 1 ♀, Toowoomba, 9.i.1964, J.C. Cardale; 1 ♀, Brisbane, 16.x.1959, D. Petty; 1 ♀, Maryborough-Granville, on young *Eucalyptus*, R.A. O'Brien; 1 ♀, Brisbane, iv.1957, N. McKenna; 1 ♂, Stanthorpe, 21.x.1924, collector missing; 1 ♂, Pialba Rd, near Maryborough, on young *Eucalyptus*, R A. O'Brien; 1 ♀, Middle Ridge, 20.x.1962, A. Macqueen; 1 ♂, Mt Norman, 23.iii.1963, G. Monteith; 1 ♀, Brisbane, 3.ii.1962, M. Tapiolas; 1 ♂, Stanthorpe, 5.iii.1924,

collector missing; 1 ♂, Dunwich, 11.iv.1965, D. Kokholm; 1 ♂, Jondaryan, 13.iv 1963, C. Speed; 1 ♂, Brisbane, iv.1955, J. Thapa (UQ). Australian Capital Territory: 2 ♂♂, Ginninderra, 7.ii.1964, J. Bancroft; 1 ♂, Black Mt, 4.iii.1964, Bancroft; 1 ♀, Yarralumla, 11.ii.1964, J. Bancroft (DASUT); 3 ♂♂, 5 ♀♀, University grounds, Black Mt, 22.i.1963, T.G. Campbell V. Henry; 6 ♂♂, 2 ♀♀, Black Mt, *Eucalyptus*, iv.1963, T.G. Campbell & H. Davies; 1 ♀, Black Mt, 3.iv.1964, T.G. Campbell; 2 ♂♂, 1 ♀, Abbatoirs site, from *E. meliodora* and *E. blakelyi*, 12.i.1967, R. McInnes; 1 ♂, 1 ♀, Black Mt, *Eucalyptus*, iv.1963, T.G. Campbell; 1 ♀, near reservoir, Black Mt, ii.1963, H. Davies; 2 ♂♂, Black Mt, iv.1964, T.G. Campbell; 1 ♂, Black Mt, 3.iv.1964, T.G. Campbell; 1 ♂, 2 ♀♀, Deakin, 18.i.1961, D.F. Waterhouse; 2 ♂♂, Canberra, x.1930, collector missing; 1 ♂, 1 ♀, Uriarra, *E. blakelyi*, 6.ii.1973, K.O. + P.H.; 2 ♂♂, Black Mt, *E. fastigata*, 31.iii.1971, H.M.; 1 ♂, Black Mt, *E. macrorrhyncha*, 20.i.1971, H.J.E.; 1 ♂, Uriarra, *E. melliodora*, 20.ii.1973, K.O. + P.H.; 1 ♀, Uriarra, *E. melliodora*, 23.x.1972, K.O. + A.M.; 1 ♂, 1 ♀, Uriarra, *E. melliodora*, 27.ii.1973, K.O. + A.M.; 1 ♂, Canberra, 2.xi.1977, A. Warren; 1 ♂, Black Mt, *E. maculata*, 23.xi.1972, H.M. K.O.; 1 ♂, Black Mt, *E. maculata*, 16.xi.1972, H.M. + A.M.; 1 ♂, Black Mt, 25.i.1973, *E. maculata*, A.M. + P.H.; 1 ♂, 1 ♀, Uriarra, *E. blakelyi*, 12.xii.1972, K.O. + A.M.; 1 ♂, 3 ♀♀, Black Mt, *E. blakelyi*, 22.x.1970, S.M. Khan; 2 ♂♂, 1 ♀, Black Mt, *Eucalyptus*, 1.ii.1984, J. James + M. Stevens; 1 ♀, Hackett, 8.ix.1972, S.G. Allen (ANIC); 1 ♀, Queanbeyan, i.1892, Lea (BCRI); 1 ♂, Canberra, *E. blakelyi*, ii.1976, L. Fox; 1 ♂, 1 ♀, Canberra, *E. globulus* subsp. *bicostata*, ii.1976, L. Fox; 2 ♂♂, 1 ♀, Canberra, *E. bridgesiana*, ii.1976, L. Fox (WAITE). Western Australia: 1 ♂, Cunderdin, ix-x.1913, collector missing; 2 ♀♀, Darlington, 24.xi.1905, L.E. Koch; 1 ♀, Kalamunda, 3.iv.1962, L.E. Koch; 1 ♀, Armadale, 20.i.1970, L.E. Koch; 1 ♂, Woolgangie, 26.xii.1963, A. Douglas; 1 ♂, 1 ♀, Dedari, 23-25.i.1962, A.M. Douglas & L.N. Mckenna; 1 ♂, Mundaring Weir, 6.iii.1963, J. Dell; 1 ♂, Merredin, 20.i.1962, A. Douglas & G.F Mees; 1 ♂, Mundaring Weir, 6.ii.1963, J. Dell; 1 ♂, Fitzgerald National Park, on foliage of *E. retragona*, 24-28.xii.1978, T.F. Houston; 1 ♀, Tutanning Reserve, *Eucalyptus*, 30.x-3.xi.1980, T.F. Houston; 1 ♂, Mt Bruce, on *E. gamophylla*, 6-15.v.1980, T.F. Houston *et al.*; 1 ♀, Comet Vale siding, on mallee, 7-15.iii.1979, T.F. Houston *et al* ; 1 ♂, Denmark, 26.v.1976, R.P. McMillan; 1 ♂, Eneabba, 9.iii.1989, R.P. McMillan (WAM); 1 ♂, Mitchell Plateau, 17.v.1983, I.D. Naumann J.C. Cardale; 1 ♂, Glenforrest, 1.xii.1933, K.R. Norris (ANIC); 1 ♂, Barren Range, 20.xii.1970, K.T. Richards; 2 ♂♂, 1 ♀, Dowerin, date missing, L.J. Newman; 1 ♂, South Perth, 14.xi.1986, P.J. Micheal; 1 ♀, Southern Cross, 13.iii.1975, K.T. Richards; 2 ♂♂, Darlington, *E. cinerea*, 20.i.1979, John Neil (WADA). Northern Territory: 1 ♂, Sandover Bore, 10.x.1977, J.A. Forrest (SAM); 1 ♀, Todd River, 10.x.1978, M.S. Upton; 2 ♀♀, near Alice Springs, 23.ix.1978, M.S. Upton; 1 ♂, Mt Cahill, 7.iii.1973, M.S. Upton; 1 ♂, Mt Borradaile, 31.v.1973, R.S. McInnes (ANIC). Victoria: 1 ♂, The Gap, Gundowring, 17.xi.1966, T.G. Campbell; 1 ♂, near Koetang, 28.x.1967, Britton & Misko; 1 ♂, Yackandandah, 16.xi.1966, T G. Campbell; 1 ♀, Nainbucca, 10.i.1952, J. Munro; 4 ♂♂, 2 ♀♀, Rutherglen, *E. camaldulensis*, 2.iii.1994, P V. Gleeson (ANIC); 1 ♀, Benalla, date missing, Helms (WADA); 1 ♀, Yarragon, 5.xi.1989, K.L. Dunn; 1 ♂, Camberwell, date missing, R T.M. Pescott (VAIC); 1 ♀, Yankee Point, 1.xii.1973, collector missing; 1 ♂, Bendigo, 14.iii.1948, J. Doyle (MV). South Australia: 1 ♂, Mitcham, *E. microcarpa*, 8.xi.1986, G. Allen; 1 ♀, Glen Osmond, *E. camaldulensis*, 10.ii.1981, G.S. Taylor (WAITE).

Amorbus subserratus (Westwood)

Material examined. 1 ♂, *Physomerus subserratus* (holotype), Melville Island, date missing, Westwood (HEC).

Amorbus n. sp. 1

Material examined. Queensland: 1 ♂, Cairns, date missing, J.F. Illingworth (QM); 1 ♂, 1 ♀, Cairns district, date missing, A.M. Lea (SAM).

Amorbus n. sp. 2

Material examined. Australian Capital Territory: 1 ♂, 1 ♀, Yarralumla Nursery, tip damage of *Eucalyptus*, 17.iv.1967, R.S. McInnes (ANIC).

Amorbus n. sp. 3

Material examined. 1 ♀, National Park, 30.ix.1904, collector missing (BCRI). Queensland: 1 ♂, Mt Tamborine, 29.ix.1977, B.K. Cantrell; 1 ♀, Mt Tamborine, 15.xi.1978, B.K. Cantrell; 1 ♀, Beerwah, 28.ix-29.x.1986, B.K. Cantrell; 1 ♀, Mt Tamborine, edge of rainforest, 14.iii.1979, K.J. Houston (DPIQ); 6 ♂♂, 1 ♀, Mt Elliot, open forest 200-800 m, 25-27.iii.1991, G. Monteith & D. Cook; 1 ♀, Mt Cougal, upper Tallebudgera Creek, 500 m, 7.iii.1988, G.B. Monteith; 1 ♀, Tambourine, 21.ii.1927, H. Hacker (QM). Australian Capital Territory: 3 ♂♂, 1 ♀, Blundell's, 7.iii.1934, F.G. Holdaway; 1 ♂, Blundell's, 21.i.1931, W.K. Hughes; 1 ♂, Black Mt, 11.i.1934, W.L. Rait; 1 ♂, Blundell's 30.iii.1930, T.G. Campbell (ANIC). Victoria: 1 ♂, Bright, 2.iii.1937, R.V. Fyfe; 1 ♂, 1 ♀, Blundell's, *E. vemin*, 30.xi.1971, H.M. K.O.; 1 ♀, Uriarra, *E. blakelyi*, 5.iv.1972, K.O. + A.A.; 1 ♀, Blundell's, 30.i.1930, J. Evans (ANIC); 1 ♀, Merrijig, 1.xii.1971, A. Neboiss; 1 ♀, Bogong Village, 3000', 26 iii.1960, A.N. (MV). New South Wales: 1 ♂, 1 ♀, Coree Creek, 12.xi.1930, J.W. Evans; 1 ♀, Durras North, i.1965, I. Cameron; 1 ♀, Pago Bk, *E. dives*, 5.xii.1972, K.O. + H.M.; 1 ♂, Devil's Pinch, near Guyra, 14.iii.1972, C.W. Frazier; 1 ♀, Lindfield, x.1985,

M. Stevens; 1 ♂, Nullo Mt, 1.xii.1951, T.G. Campbell (**ANIC**); 1 ♂, 1 ♀, Wyong, Olney State Forest, Lemon Tree Rd, *E. saligna*, 18.i.1994, C. Urquhart, A. Britton (**FCNSW**).

Amorbus n. sp. 4

Material examined. South Australia: 1 ♂, Murray River, date missing, H.S. Cope; 1 ♀, near Kimba on Eyre Highway, flowering mallee (*Eucalyptus* spp.), 2.xii.1974, S. Barker (**SAM**); 1 ♂, Loxton, 17.xii.1936, D.C.S (**WAITE**). New South Wales: 1 ♂, Bramah homestead, near Balranald, 24.x.1983, D.C.F. Rentz & M.S. Harvey (**ANIC**). Western Australia: 1 ♀, Balladonia Motel, 13.x.1968, Britton, Upton, Balderson (**ANIC**); 1 ♀, Dowerin, date missing, L.J. Newman; 1 ♀, Norseman, 22.xii.1972, K.T. Richards (**WADA**).

Amorbus n. sp. 5

Material examined. Northern Territory: 1 ♂, Brunette Downs, 22.i.1982, R. Patterson (**ANIC**). Queensland: 1 ♂, Emu Creek, 25-26.xi.1981, J. Balderson (**ANIC**). Western Australia: 1 ♀, Kimberley Research Station, 25.i.1960, K.T. Richards; 1 ♂, Kimberley Research Station, 10.iii.1960, K.T. Richards (**WADA**).

Amorbus n. sp. 6

Material examined. Queensland: 1 ♂, Indooroopilly, 20.iv.1930, A.A. Girault (**QM**). Australian Capital Territory: 1 ♀, Coroe Creek, 23.x.1929, G.F. Hill; 2 ♂♂, 2 ♀♀, Canberra, x.1929, J.W. Evans; 6 ♂♂, 2 ♀♀, Canberra, xi.1929, J.W. Evans; 1 ♀, Black Mt, 30.v.1930, W. Rafferty; 1 ♀, Black Mt, *E. macrorhyncha*, 10.xii.1971, H.M. K.D.; 1 ♂, Black Mt, *E. macrorhyncha*, 23.xi.1972, H.M. K.O. (**ANIC**). New South Wales: 1 ♀, Dee Why, 29.xii.1927, M. Fuller; 1 ♂, "Timberline" valley near Spencer, 9.xii.1971, P. Morrow; 1 ♂, 1 ♀, Lindfield, 28.xii.1982, M. Stevens (**ANIC**); 1 ♀, Barra Brui, attacking leaves *E. globoidea*, 4.ii.1962, C.E. Chadwick; 1 ♀, Iluka Turnoff, 12.iii.1981, M.I. Fletcher + G.R. Brown (**BCRI**).

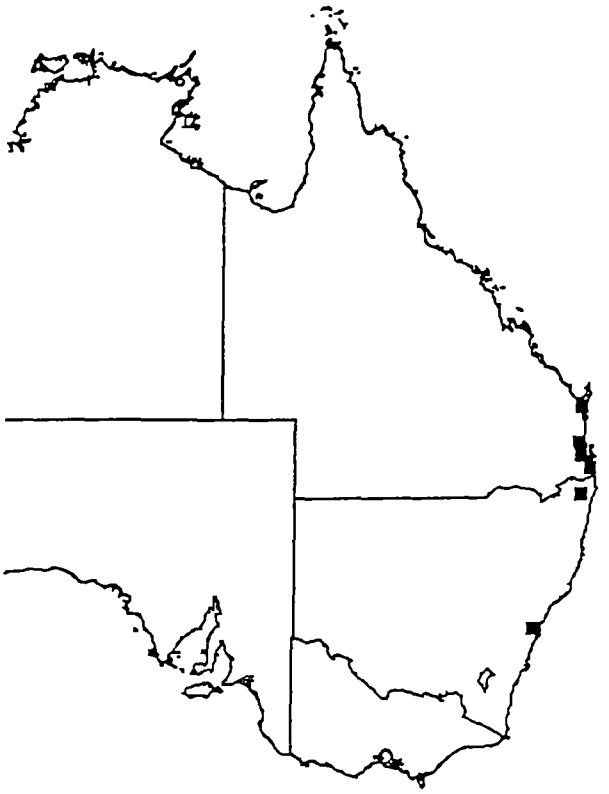
Amorbus n. sp. 7

Material examined. Queensland: 1 ♀, St Pauls, Moa (Banks) Island, Torres Strait, 16.vii.1977, G. Monteith & D. Cook; 1 ♀, airstrip Horn Island, Torres Strait, 20-22.vii.1977, G.B. Monteith (**QM**).

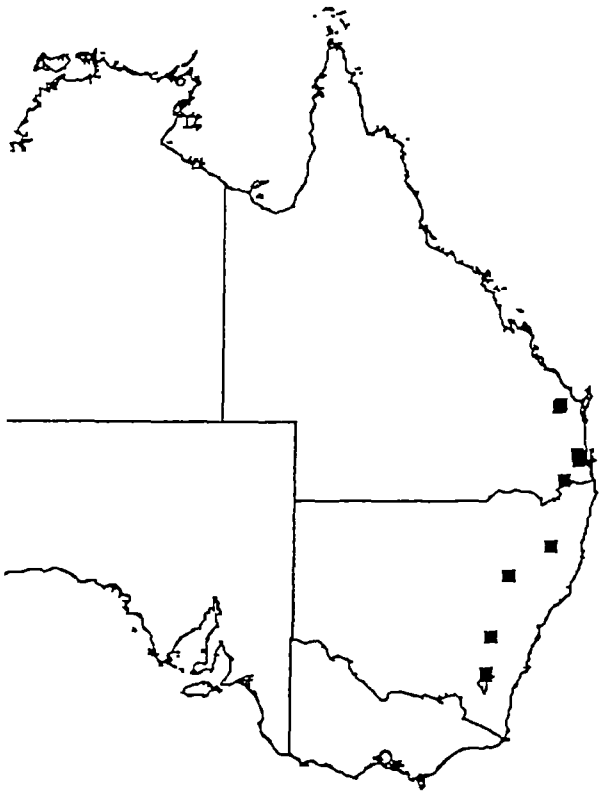
Appendix 3

• *Acantholybas brunneus* (Fig. 3.1). The only plant recorded as being associated with this species is a grass. This species also occurs in New Zealand as an introduced exotic from Australia.
• *Acantholybas longulus*. The only locality record for *A. longulus* is that of the holotype collected on Lombok Island, Indonesia.

• *Amorbus atomarius* (Fig. 3.2). The only host plant record available for this species is that of a "*Eucalyptus* sp."
• *Amorbus alternatus* (Fig. 3.3). Many of the collection records for *A. alternatus* come from arid regions which may explain the extended nature of its distribution. Unfortunately, the distributions of the few eucalypt species recorded as being associated with this species do not correlate with the insect's range of endemism. This suggests that *A. alternatus* feeds upon still other eucalypt species in addition to those cited.
• *Amorbus biguttatus* (Fig. 3.4). No host plant records are available for this species.
• *Amorbus bispinus* (Fig. 3.5). This species is restricted to south-west Western Australia and has only been recorded from Jarrah, *E. marginata*. Not surprisingly, the distribution of this coreid and it's host eucalypt are closely correlated.
• *Amorbus rhombifer* (Fig. 3.6) The host plant records for this species are not only restricted to species of eucalypt but also extend to the closely related *Angophora subvelutina*. These host plant records closely correlate with the more southern distribution of *A. rhombifer* but do not match the species' extension into central and northern Queensland, let alone northern Western Australia or northern Victoria. Should the synonymy of *A. rhombeus* with *A. rhombifer* be proven, given the opportunity to collect additional specimens from Melville Island (which is situated in the Timor Sea just off Darwin), this would extend this species distribution to this island. As this species also occurs in Papua New Guinea it is reasonable to assume that one or more of the eucalypts found there maybe hosts for this species. The eucalypt species found in Papua New Guinea include *E. alba* and *E. deglupta* (Wood 1959). Of these, only *E. alba* occurs in both countries. Thus it seems likely that *E. alba* is also a host eucalypt of *A. rhombifer*. This eucalypt is widespread in the Kimberley, W.A., across northern N.T. (including Melville Island) and in Qld. from Cape York to Rockhampton including coastal islands (Chippendale 1988). Such a distribution matches that of *A. rhombifer*.
• *Amorbus robustus* (Fig. 3.7). Unlike *A. alternatus*, the extension of *A. robustus* into the arid regions of central and northern Queensland, the Northern Territory and the Kimberley region of Western Australia appears possible given that this species has been recorded from *E. microtheca*, a eucalypt species whose range of endemism is extremely vast (Fig. 3.7d). Like *A. rhombifer*, *A. robustus* also occurs in Papua New Guinea and therefore the remarks made concerning eucalypt host plants of *A. rhombifer* are relevant to this species.
• *Amorbus rubiginosus* (Fig. 3.8). Of all the *Amorbus* species *A. rubiginosus* appears to be the most widely distributed having been recorded from all states and territories with the exception of Tasmania. In the main, collection records from Victoria and New South Wales come from high altitude and/or non-coastal localities, whilst in Queensland they are predominantly confined to coastal regions. Only in Western Australia and the Northern Territory does there appear to be any significant extension of the species into more arid inland regions. As with *A. rhombifer*, *A. rubiginosus* has also been recorded from an *Angophora* sp , namely *A. hispida*. In addition, collection record details mention some 16 species of eucalypt as having been associated with this coreid. The distributions of these eucalypts correlate well with the distribution of *A. rubiginosus* in all the states and territories except for the south-west region of Western Australia where *A. rubiginosus* has not been recorded in association with any of the endemic eucalypts.
• *Amorbus* n. sp. 1 (Fig. 3 9). The only locality record available for *Amorbus* n. sp. 1 is from Cairns in northern Queensland. No host plant records are available.
• *Amorbus* n. sp 4 (Fig. 3.10). *Amorbus* n. sp. 4 has been recorded from "flowering mallee" in South Australia, i.e. a species of eucalypt. As this common name was too non-specific to allow assignation to a particular species of eucalypt it is only possible to speculate on the species of eucalypt this coreid may be utilising. According to Chippendale (1988) a number of mallee forming eucalypt species have distributions which match quite closely that of *Amorbus* n. sp. 4; these include *E. oleosa* ("Giant Mallee" or "Red Mallee"), *E. gracilis* ("Red Mallee"), *E. foecunda* (a eucalypt with mallee habit), *E. anceps* ("Kangaroo Island Mallee") and *E. incrassata* ("Lerp Mallee"). It is possible that this coreid may utilise one or more of these species.
• *Amorbus* n. sp. 3 (Fig. 3.11). Although this species closely resembles *A. alternatus* its distribution is markedly different as it does not appear to extend into the more arid inland areas. *Amorbus* n. sp. 3 also closely resembles *A. atomarius* and the two species appear to possess very similar distributions.
• *Amorbus* n. sp. 6 (Fig. 3.12). This species closely resembles *A. obscuricornis* and has a similar distribution to the latter, however, no records of this species are known from Tasmania and/or Victoria. The distributions of the two eucalypts which have been associated with this coreid correlate closely with the collection localities of *Amorbus* n. sp. 6.
• *Amorbus* n. sp. 5 (Fig. 3 13). The three collection localities for *Amorbus* n. sp. 5 come from northern Western Australia, the Northern Territory and northern Queensland. No host plant records are available.
• *Amorbus* n. sp. 7. The only two specimens of this species have come from Banks and Horn Islands in the Torres Strait. No host plant records are available.

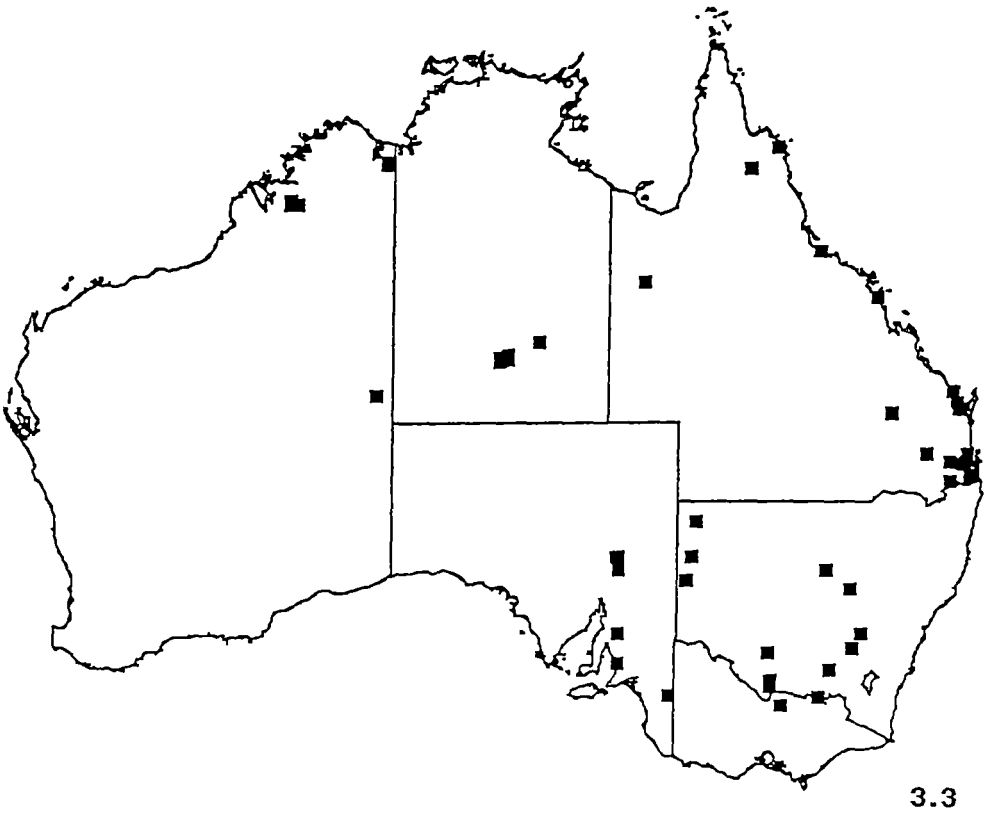


3.1

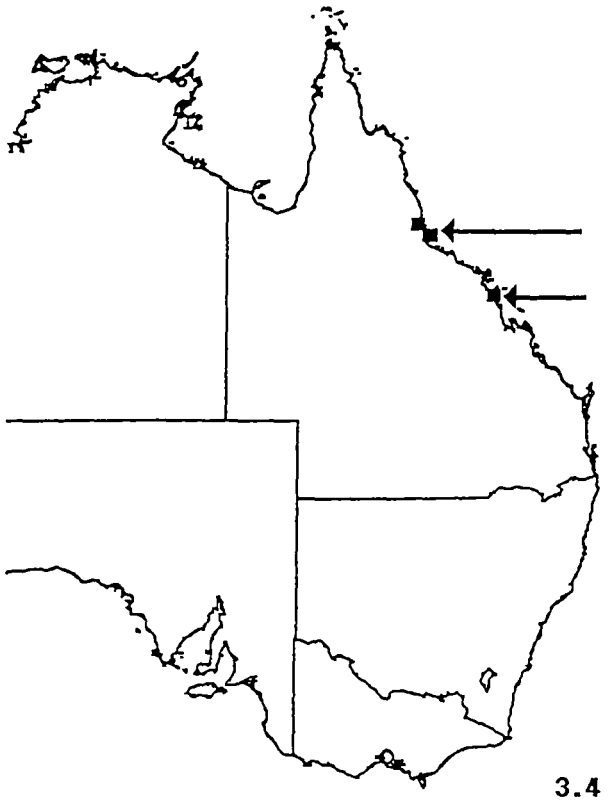


3.2

Figs 3.1, 3.2. Distribution maps of: (3.1) *A. brunneus* adults (localities in Queensland (x4) and northern New South Wales (x1) taken from Brailovsky 1993) (recorded on Gramineae in New South Wales); (3.2) *A. atomarius* adults (recorded from "*Eucalyptus* sp.").



Figs 3.3, 3.3a-3.3c. Distribution maps of: (3.3) *A. alternatus* adults; (3.3a) *E. acmenioides* (Kumar 1966); (3.3b) *E. blakelyi*; (3.3c) *E. drepanophylla* (Kumar 1966).

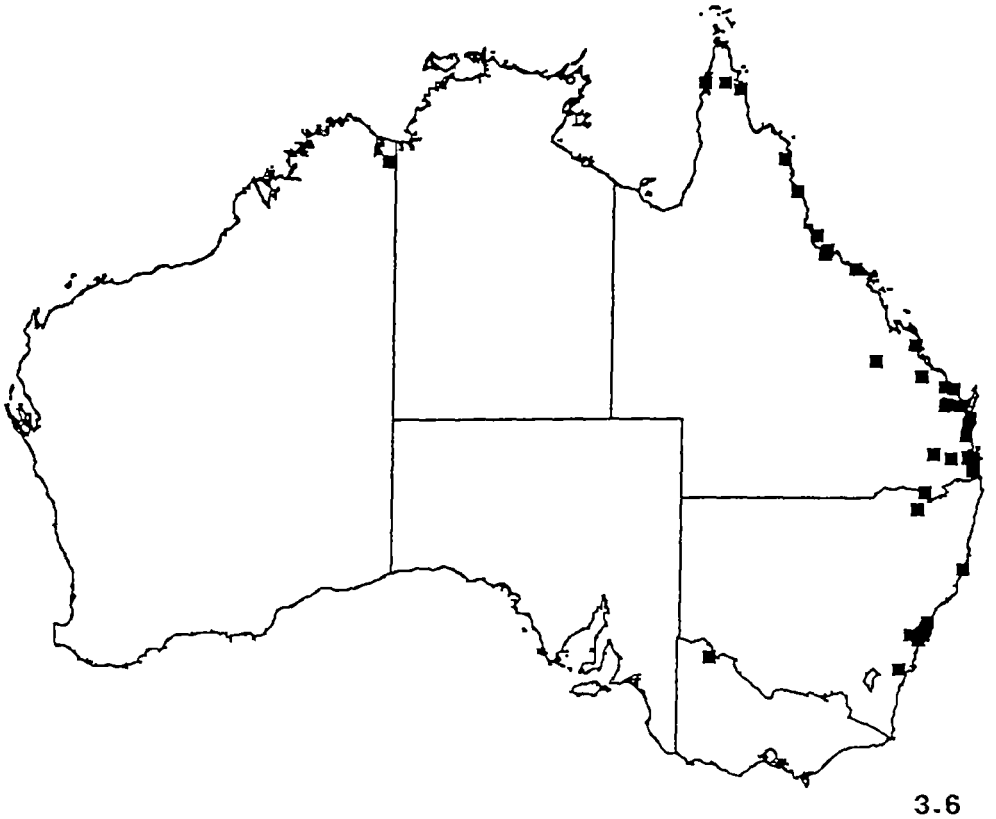


3.4

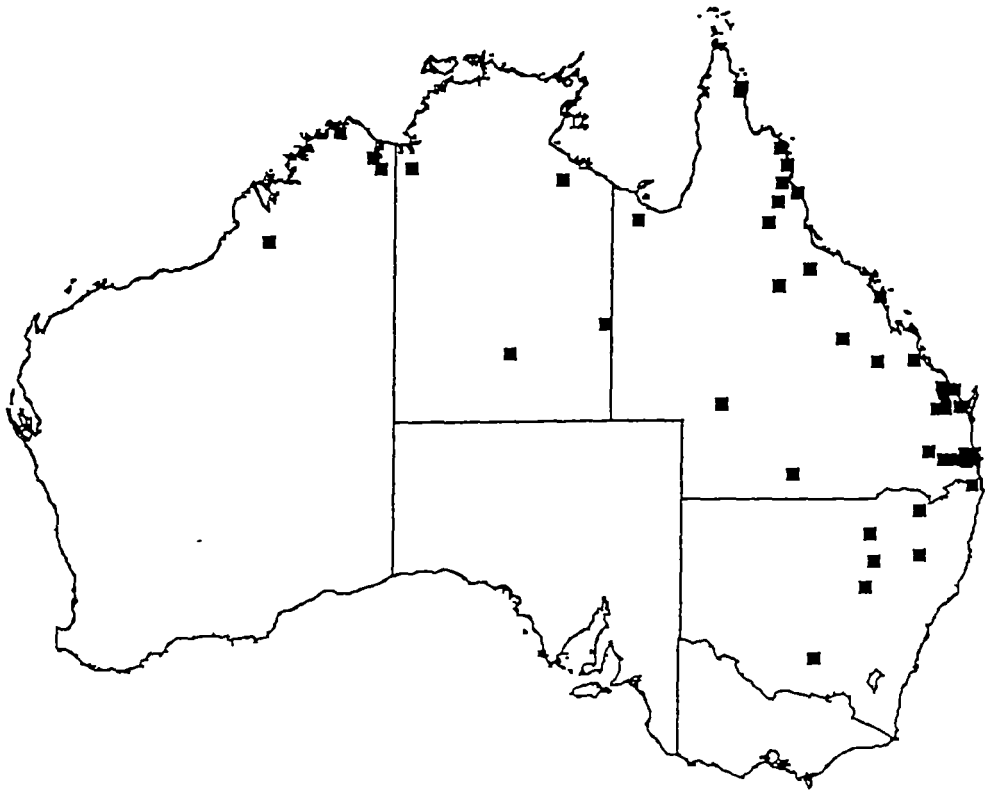
3.5a

3.5

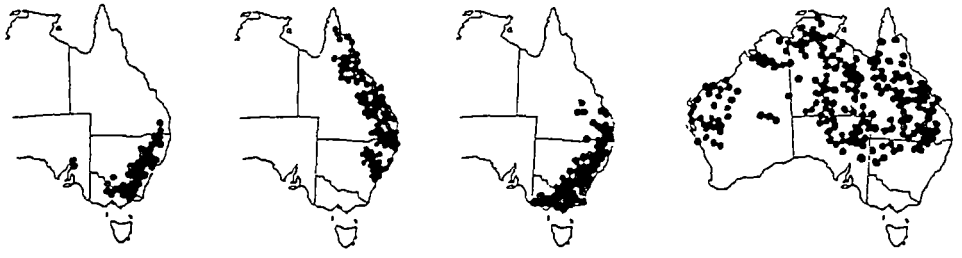
Figs 3.4, 3.5, 3.5a. Distribution maps of: (3.4) *A. biguttatus* adults (no host plant records available); (3.5) *A. bispinus* adults; (3.5a) *E. marginata*.



Figs 3.6, 3.6a-3.6c. Distribution maps of: (3.6) *A. rhombifer* adults; (3.6a) *Angophora subvelutina*; (3.6b) *E. amplifolia*; (3.6c) *E. microcorys* (Kumar 1966).

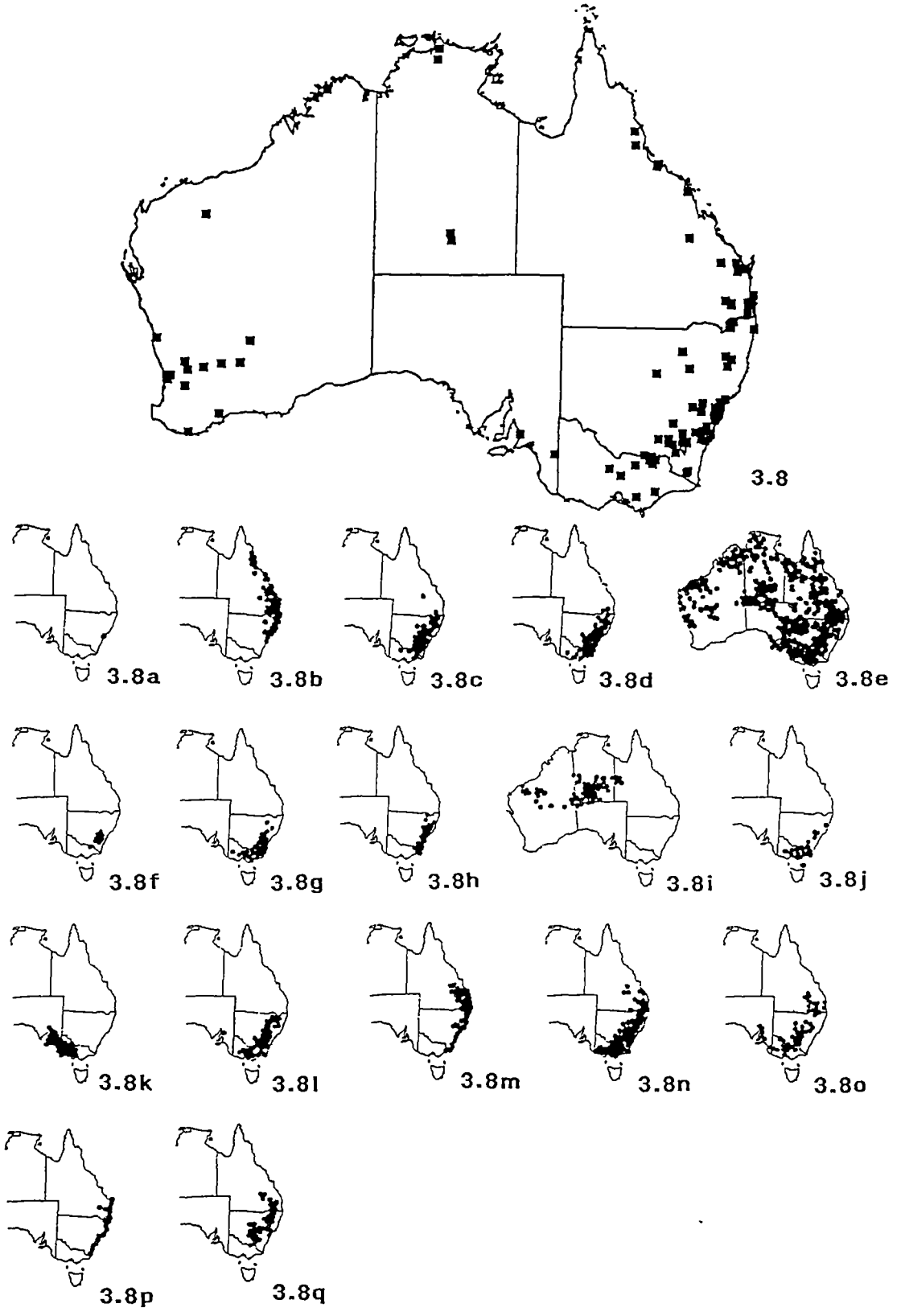


3.7

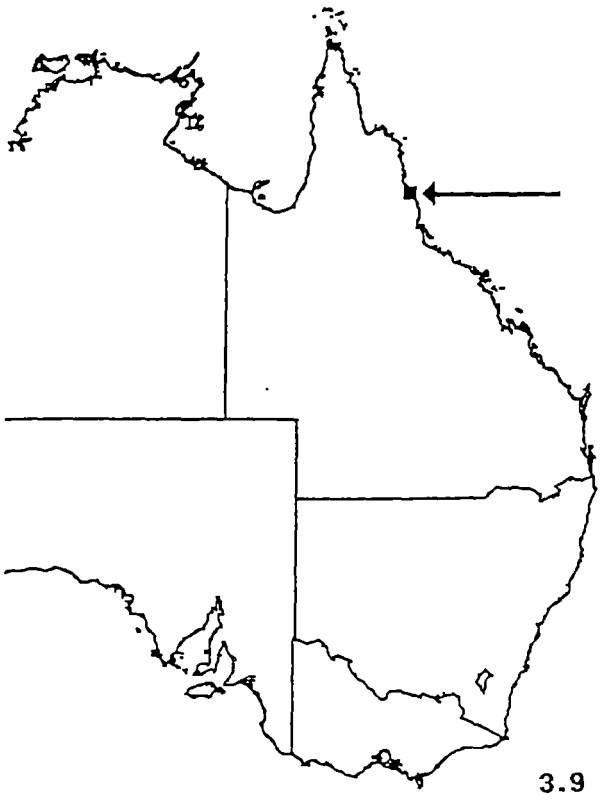


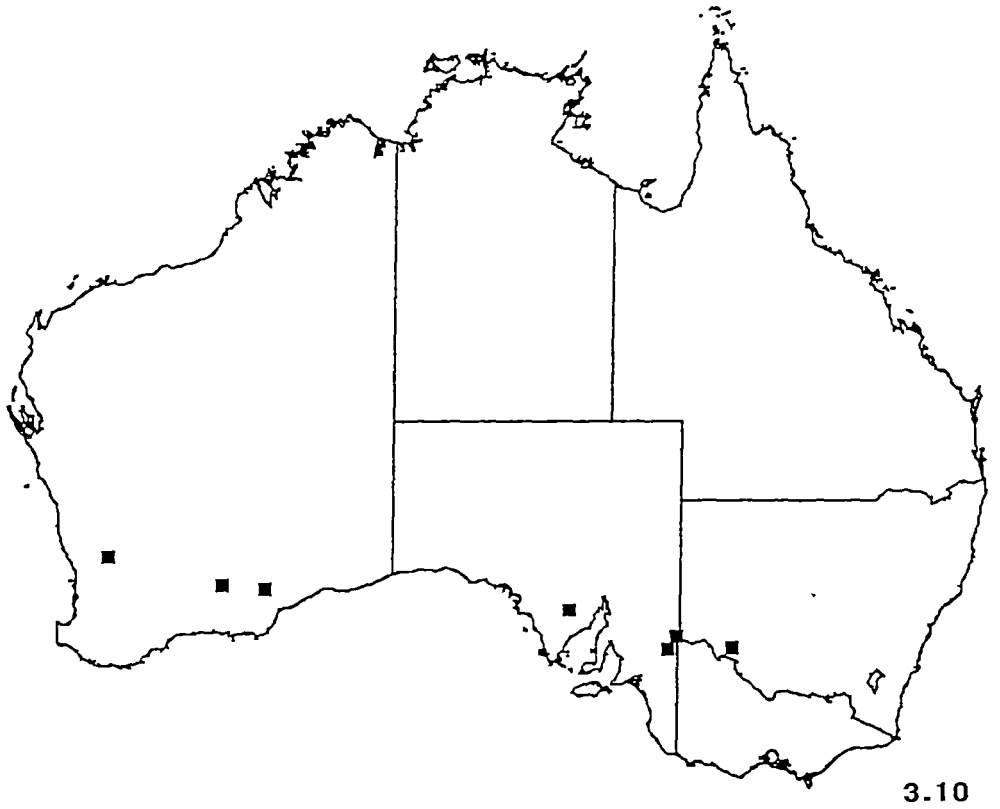
3.7a 3.7b 3.7c 3.7d

Figs 3.7, 3.7a-3.7d. Distribution maps of: (3.7) *A. robustus* adults; (3.7a) *E. albens*; (3.7b) *E. crebra*; (3.7c) *E. melliodora*; (3.7d) *E. microtheca*. (Also recorded on "ironbark" (a *Eucalyptus* sp. belonging to the series Siderophloiae) in Queensland.)

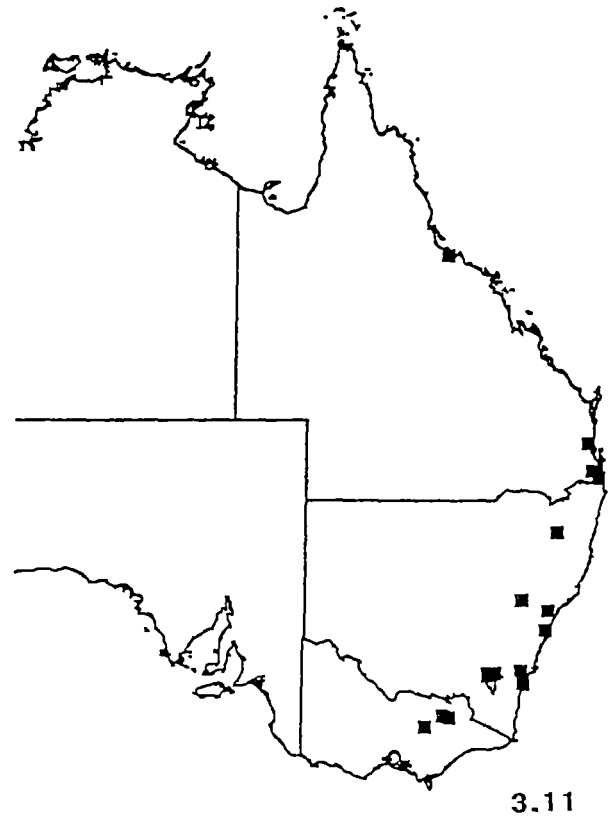


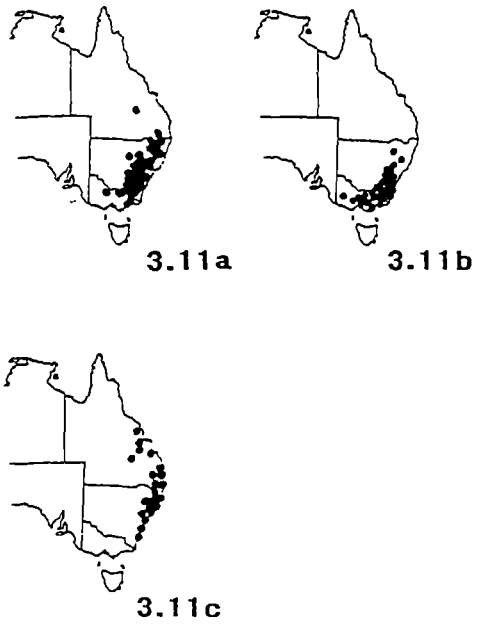
Figs 3.8, 3.8a-3.8q. Distribution maps of: (3.8) *A. rubiginosus* adults; (3.8a) *Angophora hispida*; (3.8b) *E. acmenioides* (Kumar 1966); (3.8c) *E. blakelyi*; (3.8d) *E. bridgesiana*; (3.8e) *E. camaldulensis*; (3.8f) *E. cinerea*; (3.8g) *E. dives*; (3.8h) *E. fastigata*; (3.8i) *E. gamophylla*; (3.8j) *E. globulus* subsp. *bicostata*; (3.8k) *E. leucoxylon* subsp. *leucoxylon*; (3.8l) *E. macrorhyncha* subsp. *macrorhyncha*; (3.8m) *E. maculata*; (3.8n) *E. melliodora*; (3.8o) *E. microcarpa*; (3.8p) *E. pilularis*; (3.8q) *E. sideroxylon* subsp. *sideroxylon*. (Also recorded on plantation *E. globulus* subsp. *globulus* in New South Wales; "*E. retragona*" in Western Australia and "mallee" in Western Australia.)

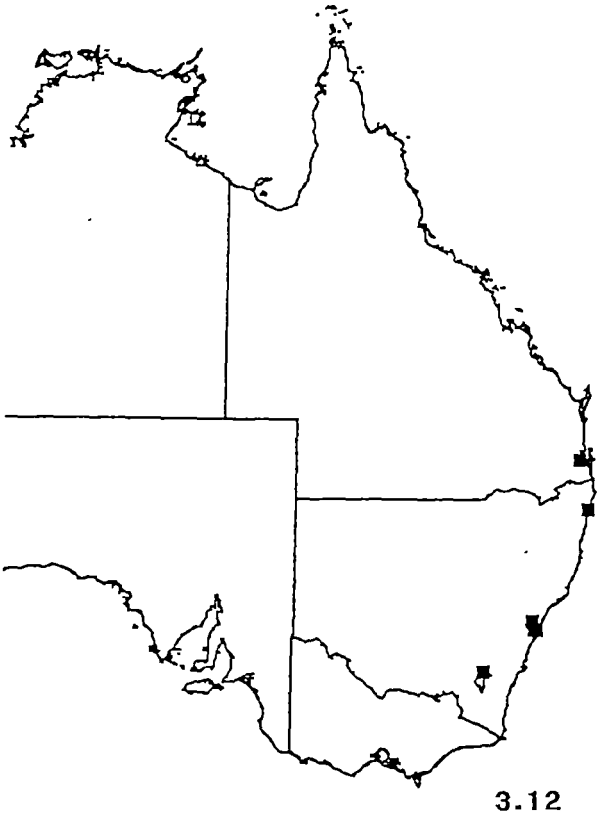


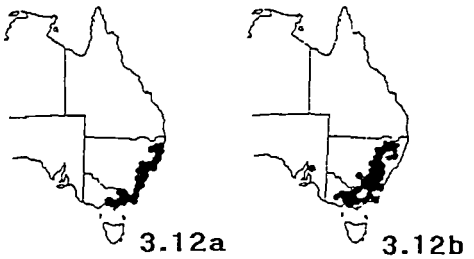


Figs 3.9, 3.10. Distribution maps of: (3.9) *Amorbus* n. sp. 1 adults (no host plant records available); (3.10) *Amorbus* n. sp. 4 adults (recorded on "flowering mallee" in South Australia).









Figs 3.11, 3.11a-3.11c, 3.12, 3.12a-2.12b. Distribution maps of: (3.11) *Amorbus* n. sp. 3 adults; (3.11a) *E. blakelyi*; (3.11b) *E. dives*; (3.11c) *E. saligna* (also recorded on "*E. vemin*" in the Australian Capital Territory); (3.12) *Amorbus* n. sp. 6 adults; (3.12a) *E. globoidea*; (3.12b) *E. macrorhyncha* subsp. *macrorhyncha*.

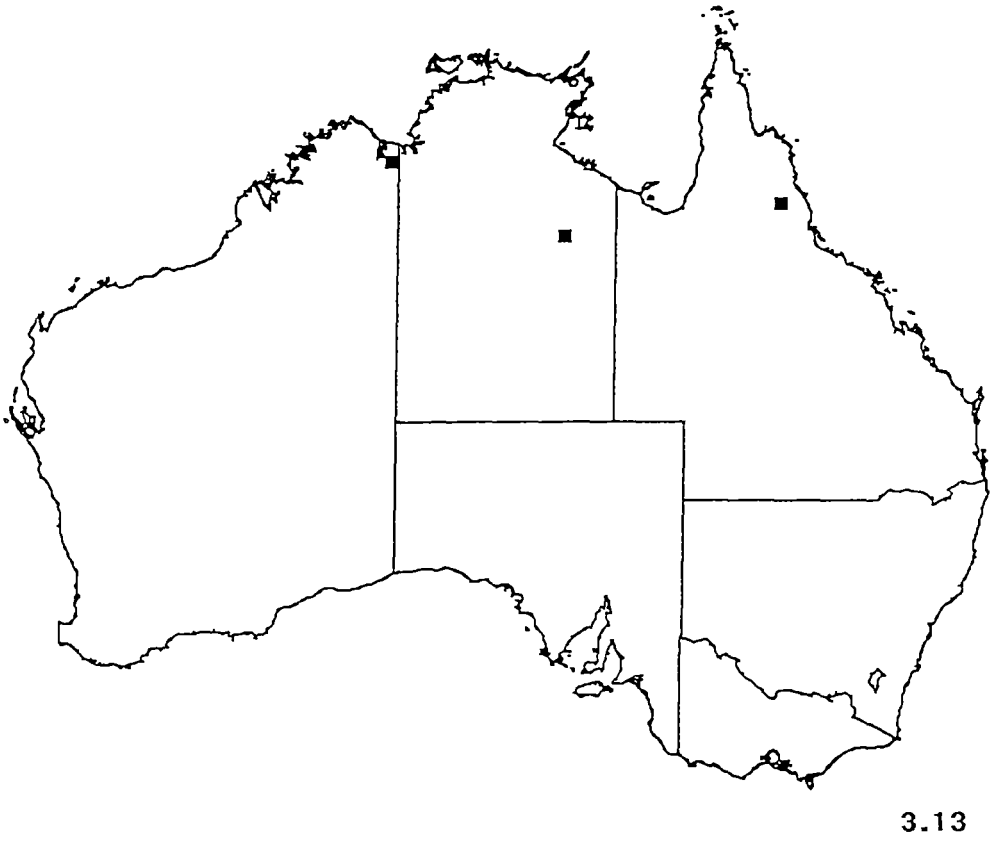


Fig. 3.13. Distribution map of: (3.13) *Amorbus* n. sp. 5 adults (no host plant records available).